FINAL REPORT

EFFECTS OF FISHING:

EFFECTS OF FISHING RESUMPTION ON A GROUP OF PREVIOUSLY PROTECTED REEFS IN THE CAIRNS SECTION.

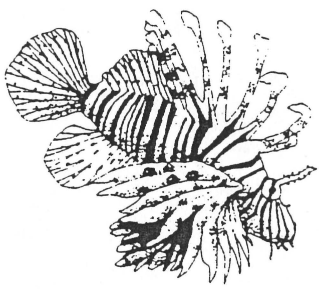
Prepared by

SEA RESEARCH

for

THE GREAT BARRIER REEF MARINE PARK AUTHORITY

November 1994



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GBRMPA REPORT STATUS

TITLE: EFFECTS OF FISHING RESUMPTION ON A GROUP OF PREVIOUSLY PROTECTED REEFS IN THE CAIRNS SECTION.

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AUTHORITY ACCEPTANCE OF REPORT: ~~MPA:~~ EXECUTIVE OFFICER

DATE: 29/11/94

DECISION relating to acceptance of report:

DECISION relating to publication of report:

AVAILABLE ON REQUEST

Name of Project Officer: JANINE KUHL

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SUMMARY

In January 1992 we made baseline surveys of large fishes and other organisms on the five protected MNP B reefs in the Cairns Section that were opened to fishing when the new zoning plan came into effect in April 1992 and on five fished 'control' reefs. The opening reefs were Ribbon #4, Escape, Channel, Wardle and Northeaster, while the appropriate 'controls' were St. Crispins, Ruby, Pellowe, Nathan and Potter. These ten reefs were resurveyed using the same techniques in February 1993, eleven months after the zoning change, to see if we could detect any change on the opened reefs. Surveys were aimed primarily at the large fishes targeted by fishermen, including coral trout, all species of lethrinid (emperors) and all species of lutjanid (snappers). In addition we made surveys of potential prey species (pomacentrids), other important reef organisms (chaetodontids, crown-of-thorns) and encrusting communities (hard coral, soft coral). Underwater visual census techniques were used for the surveys, with 50 x 10 m transects for the large fishes, chaetodontids and crown-of-thorns, and 20 x 2.5 m transects for the small prey fishes. The survey design incorporated three sites on the front of each reef and three on the back, with five replicate transects of each size counted in each site. The surveys on each reef took a day in the field using two observers. The results of the baseline survey have been reported separately (Ayling and Ayling 1992a).

Although the protection offered by the Marine Park zoning plan had been in place for eight years at the time of the baseline survey there were no differences in the density of the common coral trout *Plectropomus leopardus* between protected and fished reefs (1.42 fish per transect versus 1.39). Previous studies have also detected no effect of fishing on total coral trout density, but have found significant increases in length of coral trout on protected reefs. These studies have also suggested that there is a compensatory increase in recruitment of coral trout on fished reefs. However, The present study found no difference in length of coral trout, or density of recruits, between fished and protected reefs.

Coral trout density had decreased slightly on the opened reefs by the time of the follow-up survey in early 1993 but had also decreased on the fished controls. At the reef level there was no consistency, with a 25% decrease on one of the mid-shelf opened reefs (Wardle) but an 8% increase on the other (Northeaster).

The red-throat sweetlip *Lethrinus miniatus*, a species that was confined to mid-shelf reefs south of Cairns and is a prime target for both commercial and recreational fishermen, was recorded at significantly higher densities on protected reefs compared to fished reefs, with an order of magnitude more fish on the protected reefs at the time of the baseline survey. Previous surveys have also suggested that the density of this species is significantly

increased by protection from fishing pressure. After these protected reefs were opened to fishing the density of this species was reduced markedly on the more assessable of the opened reefs (Wardle) but did not change on the other. As a result the overall reduction on the opened reefs was not significant. Densities remained very low on the fished controls.

There were no effects of protection on the density of the combined lutjanid species, or on any of the species separately, with the exception of the stripey *Lutjanus carponotatus* which was recorded at significantly higher densities on fished reefs, the opposite of what might be expected, although this did not appear to be a real effect.

In general the density of the species and species groups counted remained constant over the twelve months between these two surveys, with significant changes only for large coral trout (a slight reduction), blue-spot coral trout (increase), hard coral cover (increase from natural growth) and coral feeding chaetodontids (increase). The power of the survey design to detect such overall changes through time was good for abundant species such as coral trout, big-eye bream and chaetodontids but not for less abundant species such as most lethrinids and lutjanids. The power of the survey to detect a change on the opened reefs relative to the fished controls (year x zone interaction) was not good. If coral trout density had been reduced to zero on the five opened reefs but had stayed the same on the five fished controls then we could have only detected this change with a type 1 error of 0.1 with 89% power.

There were no unambiguous results from this study to indicate that target fish populations had been reduced on the opened reefs eleven months after the resumption of fishing. Coral trout and red-throat sweetlip numbers may have been reduced on the most assessable of the mid-shelf reefs (Wardle) but were unchanged on the other opened mid-shelf reef. Densities of large coral trout were reduced on eight of the ten reefs and this may have indicated a general increase in fishing levels in the area but this idea was not supported by other studies over the same time period such as the Bramble Reef replenishment surveys (Ayling and Ayling 1992b, 1993, 1994).

INTRODUCTION

In their proposal for the design of a large scale experiment for measuring the effects of fishing on the Great Barrier Reef (GBR) Walters and Sainsbury suggest that the pilot study phase of the experiment be mainly aimed at testing and refining sampling methods. They also mention the possibilities of sampling on reefs that have been closed prior to the experiment and are opened at the start of the experiment but suggest that the effects of this are obvious and already fairly well understood. Although this is partly true, the opening of five Cairns Section Marine National Park B (MNP B) Zoned reefs when the new zoning plan was implemented on 3rd April 1992 provided an opportunity to test the ability of underwater visual counts of target species to detect changes in their populations.

As a result we suggested that surveys of target fish species, and a selection of other reef organisms that may be indirectly affected by fishing pressure, be made on the five protected MNP B reefs prior to the change in zoning and again eleven months after they were opened to fishing. In response to suggestions from the GBRMPA, we did not use the effects of fishing clusters as controls as was originally proposed but rather selected five 'control' reefs that were open to fishing, one for each zoning change reef and as near as possible to the opening reefs in shelf position and shape. Where possible reefs from the proposed Cairns Section effects of fishing clusters were used as 'controls'. Fished reefs were used as 'controls' because of a concurrent study looking at target fish age structure (Brown et al. 1993). That study used fished reefs for comparison with the opening reefs, and although our design should ideally have used other protected reefs as controls, we were required to use the same reefs as Brown et al. so that comparisons of underwater visual counts with standard fisheries techniques could be made.

The baseline survey was carried out between 20th January and the 7th February 1992, immediately prior to the introduction of the new zoning plan. The results from this survey were reported to the GBRMPA in July 1992 (Ayling and Ayling 1992a) and provided a baseline from which to measure changes in the follow-up survey. This survey suggested that the 10 m wide transects used slightly underestimated density when compared with previous surveys on the same reefs using 5 m wide transects. The results also showed that 8 years of protection from fishing had not affected coral trout density but may have resulted in enhanced populations of some lethrinid species, especially the red-throat sweetlip *Lethrinus miniatus*. Power analysis indicated that the visual transect technique was suitable for the powerful detection of changes in the target fish populations. The major factor affecting fish populations on the ten survey reefs was shelf position: six of the reefs were outer-shelf and four were mid-shelf, and the differences between these two groups overrode all other effects.

The post-opening survey was carried out between 26th February and 9th March 1993, eleven months after the change in zoning allowed the resumption of fishing on the previously closed reefs.

The major aim of this project was to see if we could detect changes in the density of large target fishes (coral trout, lethrinids and lutjanids) that may have been due to the resumption of fishing on the MNP B reefs after the zoning change. In addition we looked for changes in the density of a selection of potential prey of the target species (pomacentrids), other important reef species (butterflyfishes and crown-of-thorns) and the percentage cover of the major encrusting groups (hard corals, soft corals).

METHODS

Study Sites

As was pointed out in the report on the baseline survey (Ayling and Ayling 1992a) the study reefs can be grouped into four southern mid-shelf reefs offshore from Innisfail and six outer-shelf reefs between Cairns and Cooktown (figure 1, table 1). As a result shelf position was confounded with latitude in this study (all the mid-shelf reefs were in the south and the outer-shelf reefs in the north). However, the available evidence suggests that shelf position is more important than latitude in this area of the GBR, at least for coral trout (Ayling and Ayling 1986b). In a 1991 study of sixty reefs in the Cairns Section (Mapstone *et al.* 1991) there were similar differences between the outer barrier reefs between Cairns and Cooktown and the mid-shelf reefs in the same area, as there were between these northern outer barrier reefs and the southern group of mid-shelf reefs used in the present study (unpublished data held by the GBRMPA).

Table 1. Survey Reefs.

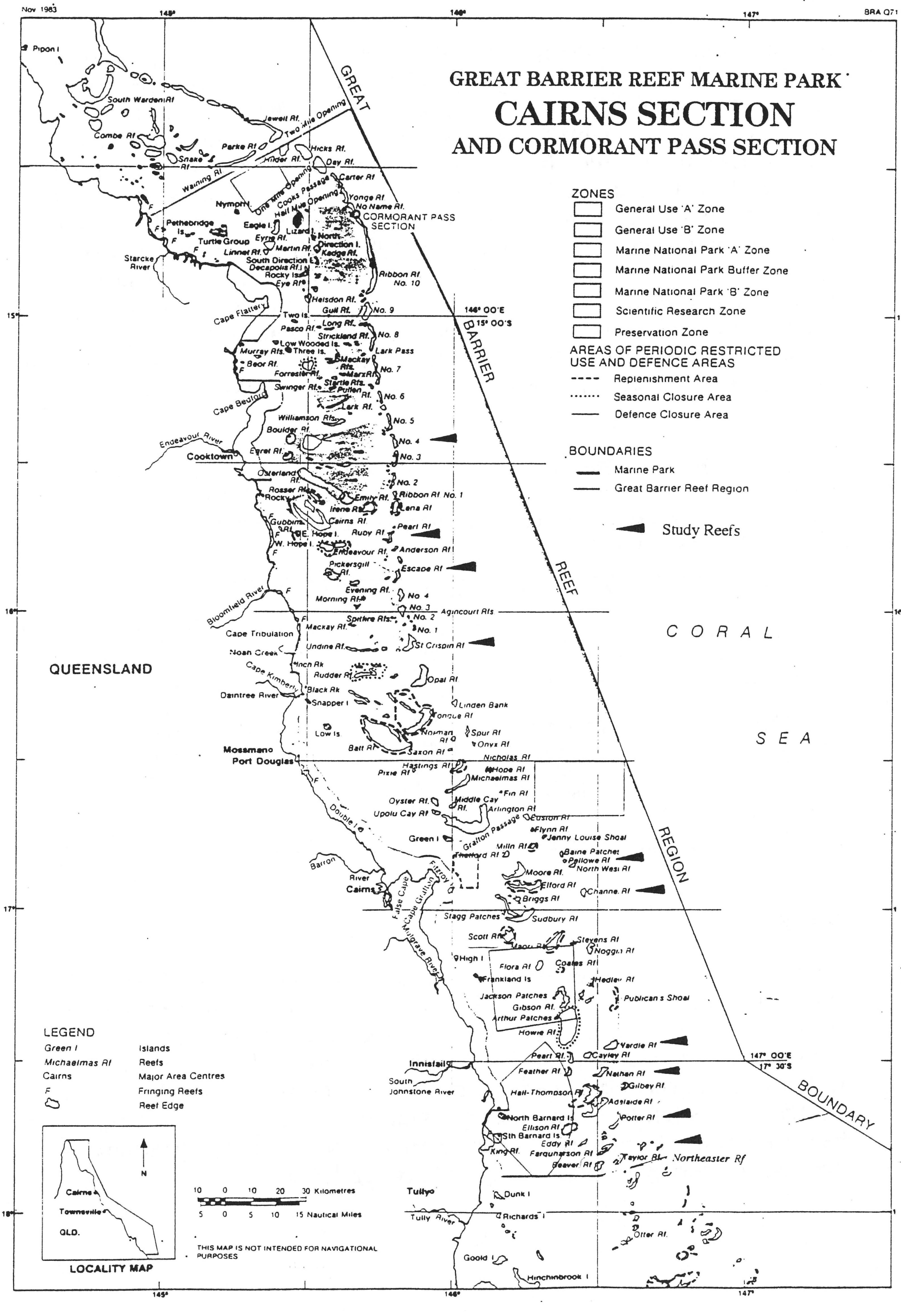
Cross shelf index ranges from 0 for a mainland fringing reef to 1.0 for a reef on the outer edge of the continental shelf.

Reef	Initial Status	Latitude	Cross-Shelf Index	Shelf Position
Ribbon #4	protected	15°26'	0.97	outer
St. Crispins	fished	16°05'	0.88	outer
Escape	protected	15°52'	0.95	outer
Ruby	fished	15°45'	0.95	outer
Channel	protected	16°57'	0.88	outer
Pellowe	fished	16°51'	0.86	outer
Wardle	protected	17°26'	0.75	mid
Nathan	fished	17°32'	0.65	mid
Northeaster	protected	17°47'	0.76	mid
Potter	fished	17°42'	0.65	mid

Design

Six sites were surveyed on each reef: three approximately evenly spaced sites in the front reef habitat and three in the back reef, with each site comprising approximately 500 m of reef edge. Five replicate 50 x 10 m transects were surveyed in each site with the transects run parallel to the reef edge and generally covering a depth range from 4-12 m. A gap of at least 50 m was left between transects, with minimum spacing of about 300m between sites. The rationale for using 50 x 10 m transects is presented in the baseline survey report (Ayling and Ayling 1992a).

Figure 1. Map of the Cairns Section Showing the Position of the Study Reefs.



Count Techniques

The methodology used was the same as that used in surveys by Mapstone et al. (1991) in the Cairns Section to estimate density of a similar suite of species. The following organisms were surveyed visually using either line or belt transects: *Plectropomus* spp., chaetodontids, all lutjanids and lethrinids, *Acanthaster planci* (50 x 10 m belt transects); selected pomacentrids and *Thalassoma lunare* (20 x 2.5 m belt transects); total live hard coral and soft coral (20 m line intersect transects); numbers of coral colonies suspected of being actively grazed by *Drupella* spp. (30 x 1 m belt transects). These methods have been found to be cost effective in previous work by Mapstone and Ayling.

Counts were made with a field team of 3 people including two divers and a boat person. One diver ran out a 50 m fibreglass tape along the reef slope at a depth of about 4-8 m. The principal observer (A.M. Ayling) followed a few metres behind the tape layer, counting coral trout, the other large target fishes and crown-of-thorns within an estimated 10 m of the seaward side of the tape. When the principal observer completed the large fish count he returned along the tape counting *Drupella* damaged corals (and undamaged coral colonies) 0.5 m each side of the first 30 m of the tape and small fishes 1.25 m each side of the final 20 m of the tape (20 x 2.5 m). The tape layer followed, winding in the tape and summing live hard coral intercepts for the first 20 m of the return and soft coral intercepts for the next 20 m of the tape.

At the start of each transect a tape was run out at right angles to the proposed transect line to give the principal observer an indication of the width of the transect. At the end of the first pass along the transect the principal observer indicated his estimate of the width of the transect and this was measured with another tape by the tape layer and recorded.

The minimum total length of fish recorded in the counts was 6 cm for coral trout, 10 cm for lethrinids and lutjanids, 4 cm for chaetodontids and 2.5 cm for pomacentrids.

Previous work on the effect of protection on coral trout populations suggests that a major effect will be an increase in the mean length of the populations on closed reefs (Ayling and Ayling, 1986b). The total length of all coral trout recorded was estimated. It has been shown that with suitable training an adequate level of accuracy can be achieved using such estimations (Bell et al., 1985). Length estimation testing was undertaken by the trout counting observer (A.M. Ayling) at the beginning and end of the survey trip using wooden trout models supplied by the GBRMPA.

Timing of the Survey

The baseline survey was carried out between the 20th January and the 7th February 1992, prior to the change of zoning in the Cairns Section on 3rd April 1992. The follow-up survey was undertaken between the 26th February and the 9th March 1993, eleven months after the MNP B reefs were opened to fishing. Each site took between 60 and 80 minutes underwater to survey, with the six sites on each reef taking approximately 9 hours including travel time between sites.

Analysis

Two different analyses were undertaken on the survey data, with suitable transformation of the raw data where necessary. To look at the effects of lifting the eight years of protection on the MNP B reefs an analysis of the balanced group of five protected reefs and five similar fished 'controls' was undertaken for the major species and species groups counted (table 2A). In addition, an analysis that was balanced with regard to shelf position was carried out by excluding the two small outer-shelf reefs, Channel and Pellowe, that were not part of the outer barrier line of reefs (table 2B). In both analyses the major factor of interest was the year x zone interaction term. If densities of target species were reduced during the eleven months of newly applied fishing pressure on the opened reefs then a significant interaction between time and zone may be expected. It was also expected that the shelf position x zone x year factor may be useful if the effect of re-opening was different on the southern mid-shelf reefs compared with the northern outer-shelf reefs.

Table 2. Survey Analysis.

A. Comparison of Fished and Protected/Opened Reefs.

Factor	Source of variation	Fixed/Random	df	Denominator
H	Habitat	F	1	S(HZRY)
Z	Zoning status	F	1	S(HZRY)
R	Reef (Z)	F	8	S(HZRY)
S	Site (HZRY)	R	80	Residual
Y	Year	F	1	S(HZRY)
	HxZ		1	S(HZRY)
	HxR(Z)		8	S(HZRY)
	HxY		1	S(HZRY)
	ZxY		1	S(HZRY)
	RxY(Z)		8	S(HZRY)
	HxZxY		1	S(HZRY)
	HxRxY(Z)		8	S(HZRY)

B. Balanced 8 Reef Survey Analysis.

Factor	Source of variation	Fixed/Random	df	Denominator
H	Habitat	F	1	S(HPZRY)
P	Shelf position	F	1	S(HPZRY)
Z	Zoning status	F	1	S(HPZRY)
R	Reef (PZ)	F	4	S(HPZRY)
S	Site (HPZRY)	R	64	Residual
Y	Year	F	1	S(HPZRY)
	HxP		1	S(HPZRY)
	HxZ		1	S(HPZRY)
	HxR(PZ)		4	S(HPZRY)
	HxY		1	S(HPZRY)
	HxPxZ		1	S(HPZRY)
	HxPxY		1	S(HPZRY)
	HxZxY		1	S(HPZRY)
	HxRxY(PZ)		4	S(HPZRY)
	HxPxZxY		1	S(HPZRY)
	PxZ		1	S(HPZRY)
	PxY		1	S(HPZRY)
	PxZxY		1	S(HPZRY)
	RxY(PZ)		4	S(HPZRY)
	ZxY		1	S(HPZRY)

RESULTS

Summaries.

The data for all the organisms recorded in both the baseline and follow-up surveys are summarised in tables i-xi in appendix 1. Anova tables for the analyses are in appendix 4.

Estimation of Transect Width.

The mean estimate of transect width for the entire 300 transects was 9.99 m with a standard deviation of only 0.71 m, and a range from 8.3 to 12.3 m (appendix 2). Reef means, for the 30 transects on each reef, ranged from 9.86 to 10.17 m. Given that there was no consistent over or under-estimation, and that the grand mean was very close to the required 10 m, no adjustment of the individual count totals was made.

Large Fishes

Coral Trout

The common coral trout *Plectropomus leopardus* showed a significant reduction in density on the opened reefs with a 21% reduction from 1.27 to 1.00 fish per transect. However, there was a similar reduction in density for this species on the fished controls, with a 17% reduction from 1.39 to 1.15 fish per transect and the year x zone interaction was not significant (table 3, figure 2). As is usually the case for this species there were significant differences between the front and back reef habitat with an overall 63% more fish recorded in the back reef surveys (1.52 vs. 0.93 fish per transect). There was also a significant density difference between outer and mid-shelf reefs, with over 4x as many common coral trout on mid-shelf reefs compared with outer-shelf reefs (2.25 vs. 0.51 fish per transect). The habitat x shelf position interaction was significant; on mid-shelf reefs there were only 18% more coral trout on the back reef compared with the front reef (2.44 vs. 2.06 fish per transect), a non-significant difference, while on outer-shelf reefs there were 8x as many common coral trout on the back reef as on the front (0.91 vs. 0.11). The site factor was not significant (table 3).

The shelf position x zone x year interaction that we were interested in was not significant The habitat x reef interaction was significant; on some reefs the difference between front and back reef density was not significant (Potter, Pellowe) while on others it was. These differences usually reflect reef-specific peculiarities of the habitat: for example, the back reef of

Table 3. Summary of the Anova Results From the Ten Reef Analyses.

This analysis does not include shelf position but includes all ten survey reefs. NS = not significant (p>0.1); * = 0.01<p<0.1; ** = 0.001<p<0.01; *** = p<0.001. *L. miniatus* - only mid-shelf reefs analysed.

Factor:	Year (Y)	Zone (Z)	Year x zone	Habi-tat (H)	Reef (R)	Site	Other significant interaction terms
Large Fishes							
SERRANIDAE							
Plectropomus leopardus	**	*	NS	***	***	NS	H*R; H*Z*Y
P. leopardus recruits	NS	NS	NS	NS	***	***	HxY
P. leopardus <35 cm TL	NS	*	NS	***	***	*	H*R
P. leopardus >35 cm TL	*	NS	NS	***	***	NS	H*R; HxZxY
P. laevis	*	*	NS	NS	***	NS	H*Z; HxR; HxRxY
LETHRINIDAE							
Lethrinids - total	NS	*	NS	NS	***	***	nil
Lethrinus atkinsoni	NS	NS	*	NS	***	***	nil
Lethrinus obsoletus	NS	NS	NS	***	NS	***	RxY; H*R*Y
Lethrinus miniatus	NS	**	NS	NS	*	*	H*R*Y
Monotaxis grandoculis	NS	NS	NS	***	***	**	nil
LUTJANIDAE							
Lutjanids - total	NS	NS	*	***	***	***	H*Z; H*R
Lutjanus gibbus	NS	**	*	***	***	***	H*Z; H*R
Lutjanus bohar	NS	NS	NS	***	***	***	H*R
Lutjanus carponotatus	NS	***	NS	NS	***	***	H*Z; H*R
Lutjanus fulviflamma	NS	NS	NS	NS	NS	***	H*Z
CHAETODONTIDAE							
Chaetodontids	NS	NS	*	**	***	***	H*R
Coral feeding chaets	*	NS	*	***	***	***	H*Z; H*R
Small Fishes							
Pomacentrus moluccensis	NS	**	NS	***	***	***	H*R
Amblyglyphid. curacao	NS	NS	NS	***	***	***	nil
Chrysiptera rollandi	NS	***	NS	***	***	***	H*Z; H*R; H*Z*Y
Plectroglyphidodon dickii	NS	NS	*	***	***	***	H*R; H*Z*Y
P. lacrymatus	NS	*	NS	NS	**	***	H*Z; H*R; R*Y
Encrusting Organisms							
Hard coral cover	***	NS	NS	NS	***	***	H*R
Soft coral cover	NS	***	NS	NS	***	***	H*Z; H*R

Table 3 (contd.) Summary of the Anova Results From the Eight Reef Analyses.

This 8 reef analysis includes shelf position but excludes Channel and Pellowe and is balanced with regard to shelf position. NS = not significant (p>0.1); * = 0.01<p<0.1; ** = 0.001<p<0.01; *** = p<0.001.

Factor:	Year (Y)	Zone (Z)	Year x zone	Shelf position (P)	Habitat (H)	Reef (R)	Site	Other significant interaction terms
Large Fishes								
SERRANIDAE								
Plectropomus leopardus	**	*	NS	***	***	***	NS	H*P; H*Z*Y; H*R*Y; R*Y; P*Z
P. leopardus recruits	NS	NS	NS	***	NS	NS	**	H*Y
P. leopardus <35 cm TL	NS	*	NS	***	***	**	*	H*P*Z; H*R
P. leopardus >35 cm TL	*	NS	NS	***	***	***	NS	H*R; P*Z; H*R*Y
P. laevis	NS	*	NS	***	NS	***	NS	H*P; H*R*Y
LETHRINIDAE								
Lethrinids - total	NS	*	NS	***	NS	NS	***	nil
Lethrinus atkinsoni	NS	NS	NS	***	NS	NS	***	nil
Lethrinus obsoletus	NS	NS	*	NS	***	NS	***	H*P; H*R*Y; H*P*Z*Y; S*Z*Y; R*Y
Monotaxis grandoculis	NS	*	NS	***	***	NS	*	H*R
LUTJANIDAE								
Lutjanids - total	NS	NS	NS	***	**	***	***	H*P; H*Z; H*R; P*Z
Lutjanus gibbus	NS	**	*	***	***	**	***	H*P; H*Z; H*R; H*P*Z; P*Z
Lutjanus bohar	NS	NS	NS	***	***	*	***	H*R
Lutjanus carponotatus	NS	***	NS	***	NS	NS	***	H*Z; H*R; P*Z
Lutjanus fulviflamma	NS	NS	NS	NS	*	NS	***	H*Z; P*Z
CHAETODONTIDAE								
Chaetodontids	NS	NS	**	***	NS	*	***	H*P; P*Z
Coral feeding chaets	*	NS	NS	***	*	*	***	H*P; H*R; H*P*Z; R*Y
Small Fishes								
Pomacentrus moluccensis	NS	**	NS	***	***	NS	***	H*R; H*P*Y; P*Z; P*Y;
Amblyglyphid. curacao	NS	NS	NS	***	***	*	***	H*P
Chrysiptera rollandi	NS	***	**	***	***	*	***	H*Z; H*R; H*Z*Y; P*Z
Plectroglyphidodon dickii	NS	NS	*	***	***	**	***	H*P; H*R; H*Z*Y; P*Z*Y; H*P*Z*Y
P. lacrymatus	NS	*	NS	NS	*	**	***	H*R; P*Z*Y
Encrusting Organisms								
Hard coral cover	***	NS	NS	***	**	NS	***	H*P; H*R
Soft coral cover	NS	**	NS	***	***	***	***	H*P; H*R; H*P*Z

Figure 2. Changes in Abundance of Large Fishes: Year x Zone Interaction.

A. Coral Trout and Lethrinids: Graphs show grand mean density per 50 x 10 m transect for all sites in each survey within each zone. Error bars are standard errors. The significance level of the interaction is shown on each graph.

KEY: ■ 1992 ░ 1993

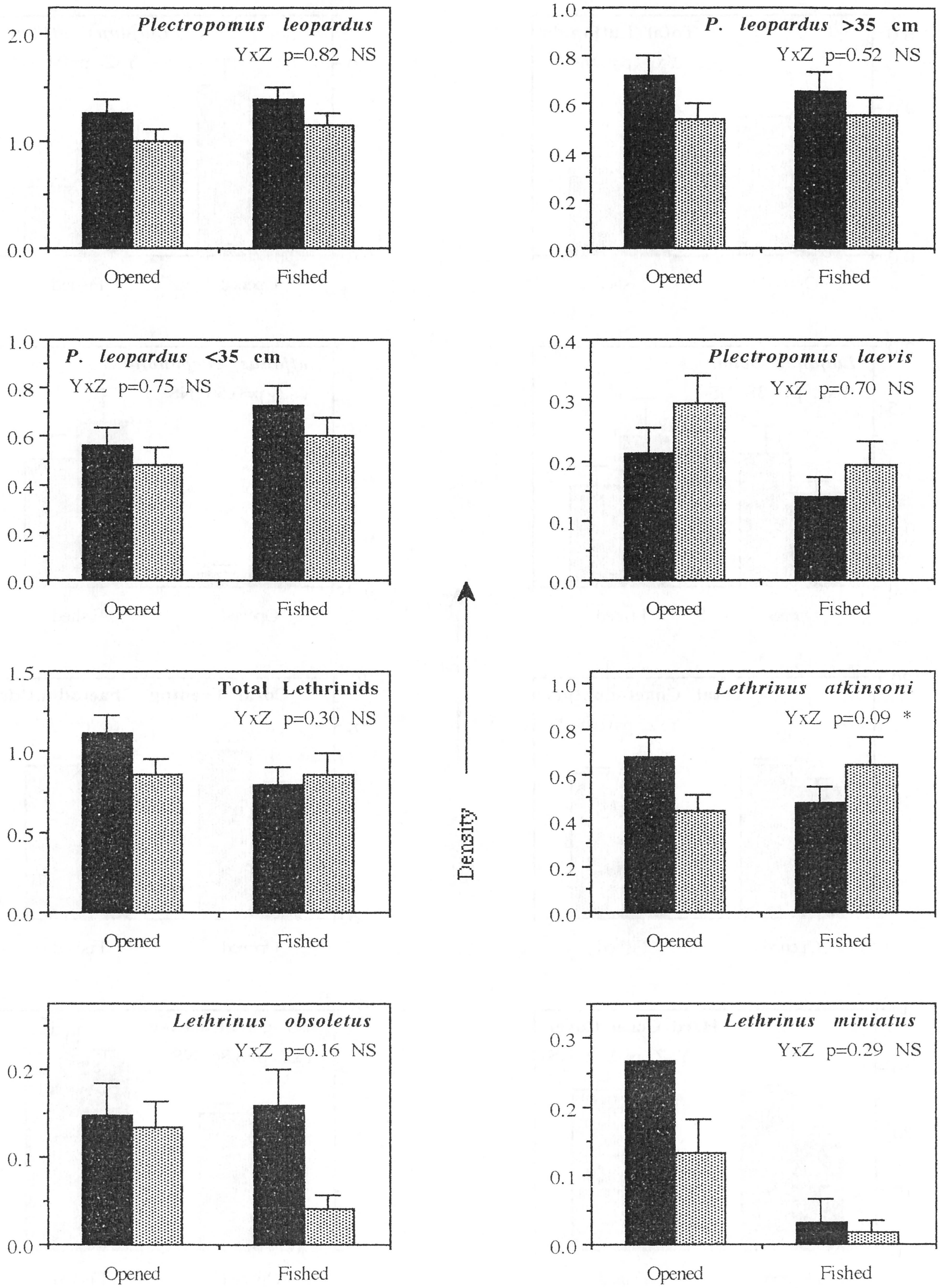


Figure 2. Changes in Abundance of Large Fishes: Year x Zone Interaction.

B. Lutjanids and Chaetodontids: Graphs show grand mean density per 50 x 10 m transect for all sites in each survey within each zone. Error bars are standard errors. The significance level of the interaction is shown on each graph.

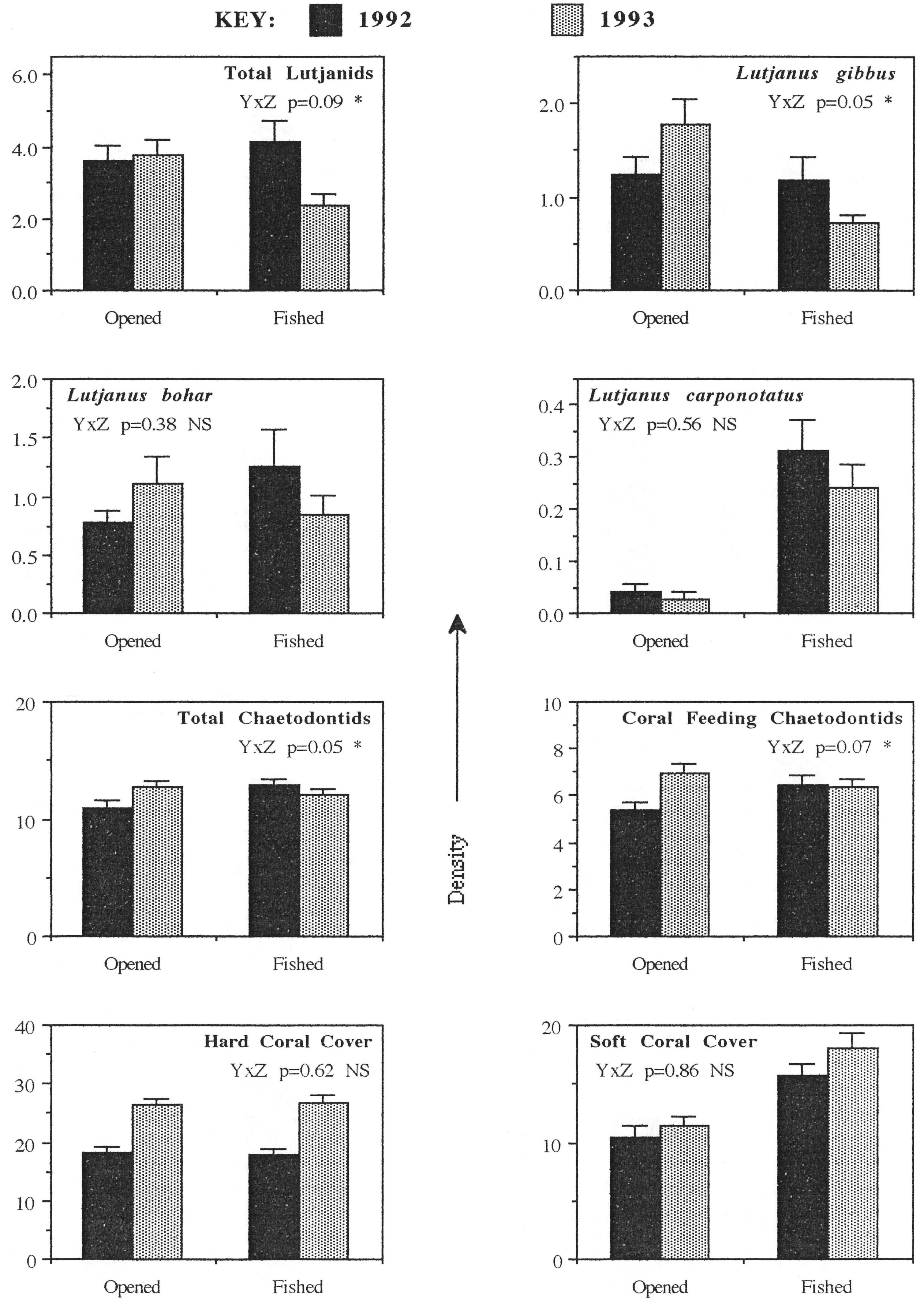
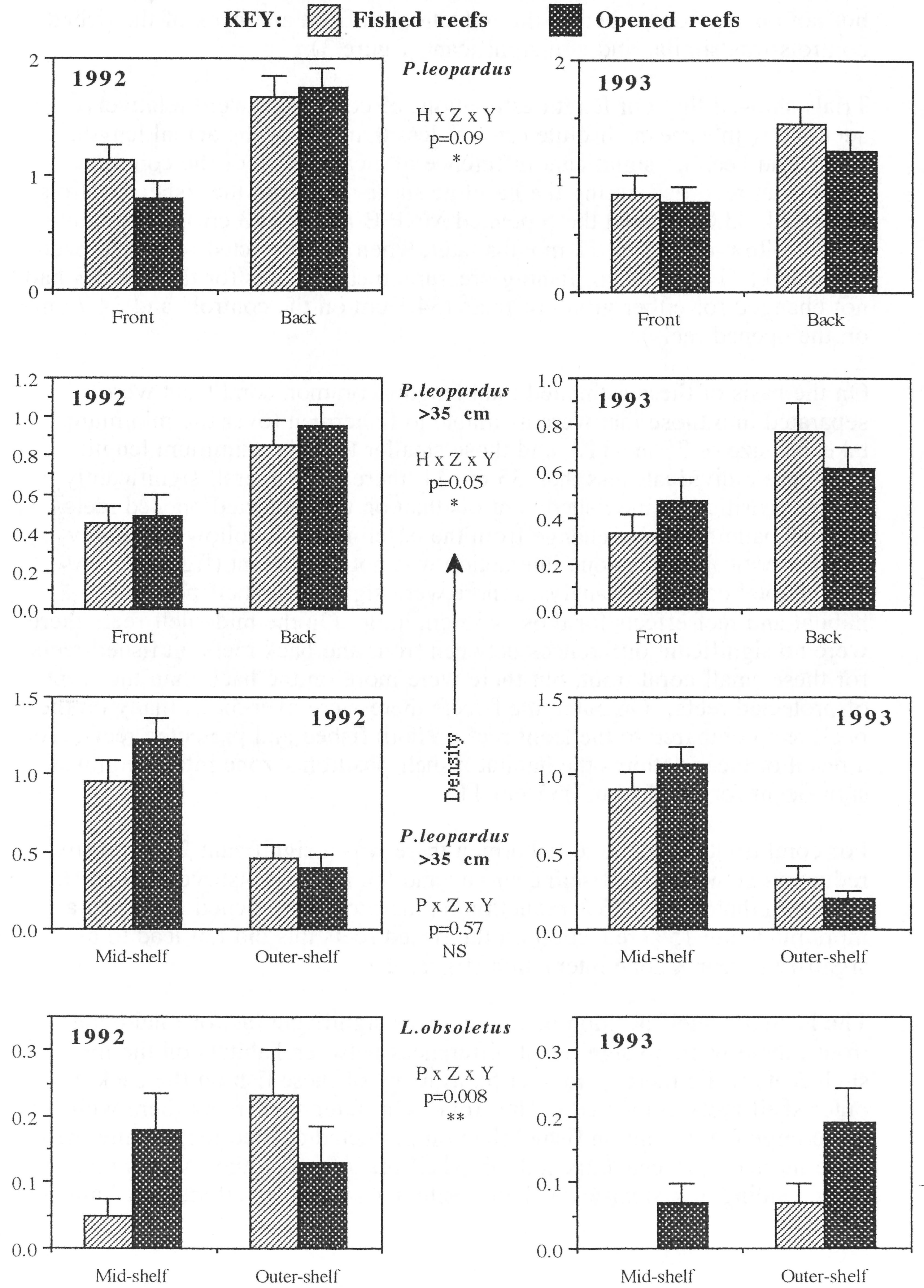


Figure 3. Effects of Fishing Resumption: Three Factor Interactions.

Coral Trout and Lethrinids: Graphs show grand mean density per 50 x 10 m transect for all sites in each category. Error bars are standard errors. Probability values for tests of significance of interactions are shown between each pair of graphs.



Potter is very sandy with only patchy, narrow reef outcrops, not ideally suited to coral trout. The habitat x zone x year interaction was also significant; there was a significant reduction on the back of the opened reefs but not on the front, whereas the reduction on front and back of the fished controls was similar and non-significant (figure 3).

Trials showed that our length estimations of coral trout were relatively accurate with a mean absolute error of less than 5% of the actual length. There had been no significant difference in mean length of the common coral trout recorded during the baseline survey between the fished controls (mean TL 33.0 cm) and the protected MNP B reefs (34.3 cm). At the time of the follow-up survey 12 months later, when the protected reefs had been subjected to 11 months of fishing pressure, mean lengths for this species had not changed for either group of reefs (34.1 cm on the controls and 34.7 cm on the opened reefs).

On the basis of these estimated total lengths common coral trout were separated into those that were available to fishermen (over the minimum takeable size of 35 cm TL), and those smaller than the minimum length. For those individuals less than 35 cm TL there were overall significantly higher densities on the fished controls than on the protected/opened reefs but this pattern did not change from the baseline to the follow-up survey and the critical year x zone interaction was not significant (figure 2). As for the total coral trout analyses there were significant shelf position, habitat and reef effects for those <35 cm long. On the mid-shelf reefs there were no significant differences between front and back reefs on fished reefs for these small coral trout, but there were more on the back than the front of protected reefs. On outer shelf reefs there were over 5x as many on the back reef compared to the front reef on both fished and protected reefs. As a result of these patterns the habitat x shelf position x zone interaction was significant for coral trout <35 cm TL.

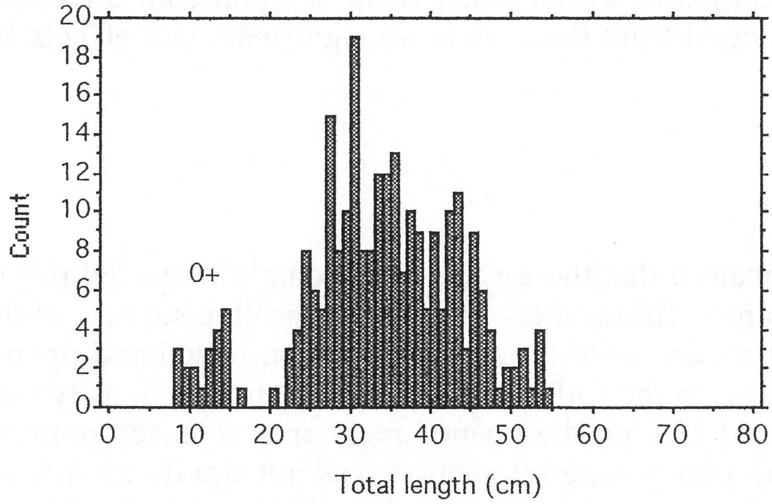
For coral trout available to fishermen there was a significant 20% density reduction between the baseline survey and the follow-up survey (table 4). Although there was a 25% reduction on the protected/opened reefs and a more moderate 15% reduction on the fished reefs this did not lead to a significant year x zone interaction (figure 2).

The habitat x shelf position interaction was significant (as for total coral trout); there were no significant differences between habitats on the mid-shelf reefs while there were over 5x as many of these fish on the back of outer-shelf reefs compared to the front. On outer-shelf reefs there were more large coral trout on fished than on protected/opened reefs while there were more on protected/opened mid-shelf reefs than on the fished mid-shelf reefs, leading to a significant shelf position x zone interaction. The habitat x zone x year interaction that was significant for total coral trout was also significant for trout over 35 cm long (figure 3).

The mean length of coral trout over 35 cm was 43.1 cm on the protected reefs during the baseline survey, not significantly different from the mean of 42.7 cm recorded on the fished reefs for this size class. Mean lengths for this fished size class were the same during the follow-up survey for both protected/opened reefs (42.0 cm) and fished reefs (42.4 cm).

Figure 4. Length frequencies of the common coral trout: 1993.

Mid-shelf reefs only. The 0+ peak is indicated.



Using the length estimations we were also able to separate 0+ recruits from the rest of the coral trout population and look at the patterns of their distribution. Juveniles settle during December and are secretive until they reach a length of about 7 cm, at which time they begin to swim up off the bottom and can be recorded in the counts (Fowler et al. 1991; A.M. Ayling personal observations). These new recruits were between 7 and 16 cm TL at the time of these surveys (figure 4), but the number recorded was probably lower than if the counts had been made a few months later. Coral trout recruit density on these reefs was very similar between the two surveys. The majority of recruits were recorded on the mid-shelf reefs (figure 4), with only three individuals counted on the five outer-shelf reefs. On mid-shelf reefs densities were approximately the same in the front and back reef habitats. There were also no significant differences between the opened and fished control reefs or between reefs in each shelf position, but there were significant differences between sites suggesting that recruits were patchily distributed at this scale (table 3).

The footballer/bluespot coral trout *Plectropomus laevis* was almost an order of magnitude less abundant than the common coral trout, with a grand mean of 0.21 fish per transect. There were 34% fewer *P. laevis* on fished reefs compared with protected/opened reefs, a significant difference, but this difference was the same during both the baseline and follow-up surveys (33% vs 34%) and the year x zone interaction was not significant (figure 2), although there was a significant increase on both fished and opened reefs during this study.

Habitat differences were not significant (table 3), although the interaction between habitat and shelf position was: there were higher densities of this species on the front of outer-shelf reefs compared with the back but the opposite on mid-shelf reefs. There were almost twice as many *P. laevis* on outer-shelf reefs compared to mid-shelf reefs, a significant difference. As with the common coral trout there were no significant site effects for this species.

Lethrinids.

There was an indication that there were significantly more lethrinids on protected reefs than on fished reefs during the baseline survey, with a significant result for zone even though densities on fished and opened reefs were almost identical in the follow-up survey. Although density had apparently decreased 23% on the opened reefs and increased nominally on the fished reefs the year x zone interaction was not significant for this important group of target species (figure 2). There were significantly more lethrinids on outer-shelf reefs than on mid-shelf reefs (1.23 fish per transect vs. 0.43). Although there were nominally fewer lethrinids in the front reef habitat than in the back reef these differences were not significant. This group of fishes is characterised by very patchy distributions, reflected in the very significant site effect in all the analyses.

Nine species of lethrinids were recorded during this survey, but only two of these, the yellow-tailed emperor *Lethrinus atkinsoni* and the orange-striped emperor *L. obsoletus*, were at all common. Separate analyses were carried out for these two species plus the commercially important red-throat sweetlip *L. miniatus* although this latter species was relatively uncommon in the counts with grand means of less than 0.1 individuals per transect. *L. atkinsoni* was the only species that showed a significant year x zone interaction that may have resulted from fishing pressure with a reduction in density on the opened reefs combined with an increase on the fished controls (figure 2). This species was significantly more abundant on outer-shelf reefs than mid-shelf reefs, but did not show any significant habitat preference within reefs.

The commercially important species *L. miniatus* was found only on the mid-shelf reefs and was significantly more abundant on the protected/opened reefs in this shelf position than on the fished reefs. This species was virtually absent from the fished reefs during both the baseline and follow-up surveys but was present in moderate numbers on the protected mid-shelf reefs during the baseline survey. At the time of the follow-up survey no individuals of this species were seen on Wardle, the closest of the two mid-shelf opened reefs to shore, but numbers on Northeaster, the other opened mid-shelf reef were approximately the same as during the baseline survey. As a result the year x zone interaction term was not significant in spite of the 50% reduction in the density of this species on the opened reefs.

L. obsoletus was more abundant in the back reef habitat, without a significant cross-shelf effect. Of the lethrinids this was the only species significant interaction terms, although the reasons for the patterns are not obvious. There were significantly higher densities of this species on the back of outer-shelf reefs compared to the front but no difference between the back and front of mid-shelf reefs, giving a significant habitat x shelf position interaction. The shelf position x zone x year interaction was significant because numbers increased on the outer-shelf protected reefs between the two surveys but decreased on the mid-shelf protected/opened reefs over the same time (figure 3).

The commonest species in the family Lethrinidae was the big-eye bream *Monotaxis grandoculis*, recorded at a grand mean density of 2.51 per transect. Although his species is not caught by fishermen as it does not take a hook there were significantly lower densities on the fished reefs compared with the protected/opened reefs for the 8 reef analysis (2.52 vs 2.87 fish per transect). It was found in significantly higher densities in the back reef habitat compared to the front reef (2.90 fish per transect vs. 2.07), and on outer-shelf reefs compared to mid-shelf reefs (2.94 vs. 1.87).

Lutjanids.

Lutjanids were more abundant than lethrinids, with a combined grand mean density of 3.48 fish per transect. Although there were no significant year or zone differences in total lutjanid density, the year x zone interaction was just significant at the 0.1 probability level. However, this was due to a slight increase (4%) on the opened reefs and a marked 43% decrease on the fished reefs, the opposite of what might be expected if fishing increased on the opened reefs (figure 2). In fact numbers of this family decreased on all five fished control reefs.

There were significantly higher densities on the front reef compared to the back and on the outer-shelf reefs compared to the mid-shelf reefs. On mid-shelf reefs habitat differences were not significant, whereas on outer-shelf reefs there were far more lutjanids on the front than the back, giving a significant habitat x shelf position interaction (table 3). Several other interactions were significant in the analysis of lutjanid results, including habitat x zone, habitat x reef and shelf position x zone. Similar interactions were shown in the separate analyses of the schooling species. As for lethrinids, the distribution of these fishes was very patchy at the scale of sampling used for this survey and there were significant site effects for all species.

Fourteen species of lutjanids were recorded during this survey but only four of these were common enough to enable separate analyses of distribution patterns to be made. The paddletail *Lutjanus gibbus* was the most abundant species and showed similar patterns to those described above for lutjanids as a whole. There was a significant difference between the fished and the protected/opened reefs and a significant year x time interaction (figure 2). As for total lutjanids this was the opposite of what we expected with a 37% increase on the opened reefs and a 40% decrease on the fished controls. This species was over 4x as abundant on the front of outer-shelf reefs than in any other location.

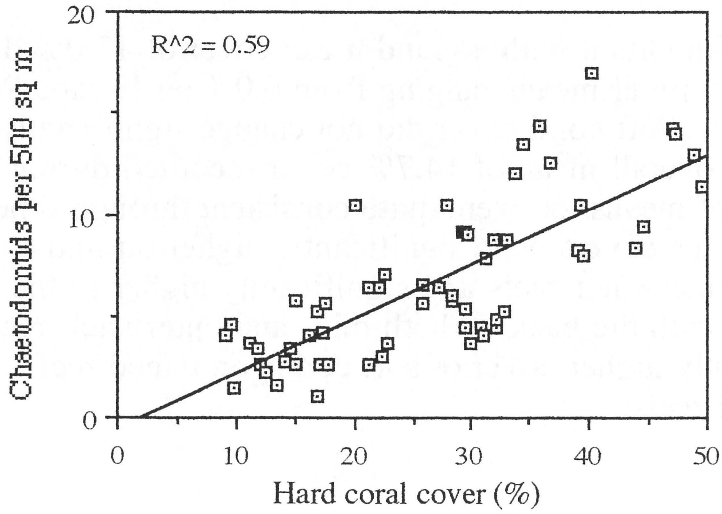
The red bass *L. bohar* was also most abundant on the front of outer-shelf reefs, and more abundant on outer-shelf reefs than mid-shelf reefs. Although the year x zone interaction was not significant for this species (figure 2) it showed similar patterns to those of the paddletail. The five-lined seaperch *L. quinquelineatus*, on the other hand, showed no habitat preferences, and was virtually absent from outer-shelf reefs, a very similar pattern to that shown by the stripey *L. carponotatus*. The stripey was significantly more abundant on the mid-shelf fished reefs than the protected/opened reefs but this pattern was not universal; Beaver Reef, a protected mid-shelf reef counted during the baseline survey had 3x higher densities of this species than Nathan and Potter, the two fished mid-shelf reefs. Although the black-spot snapper *L. fulviflamma* was nominally most abundant on the front of outer-shelf reefs it showed no significant abundance patterns with the exception of site and the habitat x zone interaction; numbers were significantly greater on the front of protected/opened reefs compared with the back (9x) but greater on the back of fished reefs (2x).

Chaetodontids.

Chaetodontids (butterflyfishes) were common at this scale of sampling, with a grand mean density from this survey of 12.16 per transect. There was a significant year x zone interaction for chaetodontid density, with a slight increase in numbers on protected/opened reefs and a slight decrease on the fished controls (figure 2). Overall there were almost twice as many chaetodontids on outer-shelf reefs as on mid-shelf reefs. Slightly more than half of the chaetodontids recorded were obligate hard coral feeders (6.28 per transect). The density of these species increased between the baseline and follow-up survey, in line with a marked increase in hard coral cover. As would be expected there was a significant positive correlation between the density of these coral feeding species of chaetodontids at each site and the cover of living hard coral at that site, both during the baseline survey (Ayling and Ayling 1992a) and in the follow-up survey (figure 5). As a result there was a significant site effect in the distribution of chaetodontids. Both total chaetodontids and hard coral feeding chaetodontids showed a significant habitat x shelf position interaction; there were significantly higher densities of both groups on the front of mid-shelf reefs compared to the back but higher densities on the back of outer-shelf reefs compared to the front, the same pattern exhibited by hard coral cover. There were also significant habitat x reef and reef x year interactions for hard coral feeders

Figure 5. Relationship of Chaetodontid Density to Hard Coral Cover - 1993.

Density of hard coral feeding chaetodontids per 500 sq m transect is shown for each site.



Small Fishes.

Analyses were only carried out for the five most abundant pomacentrids (table 3). Most species were significantly more abundant in the back reef habitat than in the front reef habitat, and on mid-shelf reefs than outer-shelf reefs, with the exception of *Plectroglyphidodon lacrymatus*, which showed no significant cross-shelf or habitat trends, and *Plectroglyphidodon dickii* which was only abundant on the front of outer-shelf reefs. Three species, *Pomacentrus moluccensis*, *Chrysiptera rollandi* and *Plectroglyphidodon lacrymatus*, showed significant zoning differences, the former two being more abundant on fished reefs than protected reefs, and the latter more abundant on protected reefs. Only *Chrysiptera rollandi* showed a significant year x zone effect, and only for the 8 reef analysis, with an increase in density on the opened reefs and a decrease on the fished controls.

Other Organisms.

The grand mean hard coral cover from all the survey reefs was 17.9% at the time of the baseline survey, with reef means ranging from a low of 10.2% on Nathan Reef to a high of 24.9% on Escape Reef. During the follow-up survey 12 months later mean coral cover had increased to 26.6%, an almost 50% increase.

Living coral percentage cover was significantly higher on outer-shelf reefs compared with mid-shelf reefs. On outer-shelf reefs there was higher coral cover on the back reef than the front reef but this pattern was reversed on mid-shelf reefs. Overall there was significantly higher cover in the front reef habitat than in the back. There were no significant differences in hard coral cover between fished and protected/opened reefs during either survey.

Soft corals were also important with a grand mean cover of 13.0% during the baseline survey, with reef means ranging from 6.0% on Escape Reef to 21.2% on Wardle Reef. Soft coral cover did not change significantly through time, with an overall mean of 14.7% cover recorded during the follow-up survey. Reef means too were quite consistent through time (appendix 1). Percentage covers were significantly higher on mid-shelf reefs compared with outer-shelf reefs and significantly higher in the front reef habitat compared with the back on both mid- and outer-shelf reefs. There was a significantly higher cover of soft corals on fished reefs compared to protected reefs.

DISCUSSION.

Characteristics of the Survey Reefs.

It is worth considering here how comparable the survey reefs are. Are all the ten reefs similar? It is clear that mid-shelf reefs as a group differ markedly from outer-shelf reefs, with all except three of the species analysed showing significant cross-shelf differences (table 3). The reefs surveyed within each shelf position and within each zone type were generally similar, with the reef factor not significant for most organisms (table 3).

Channel and Pellowe Reefs were generally similar to the other outer-shelf reefs but coral communities on the front reef had been badly damaged by tropical cyclone Joy in December 1990, especially on Channel. These were the two reefs that were excluded from the 10 reef analysis to get an 8 reef design that was balanced with respect to shelf position. Although the results were generally similar from both analyses (table 3) there were slight changes for five of the 27 species or species groups due to the cyclone damage affecting the distribution of small fishes, encrusting organisms and chaetodontids on these two reefs.

Effects of Fishing on Target Species.

Coral trout are the most sought after of the reef fish species, both by commercial and recreational fishermen. Previous studies we have made have suggested that fishing pressure has no significant effect on the density of the common coral trout *Plectropomus leopardus* (Ayling *et al.* 1991), a finding that was further supported by the results of the baseline survey from this study (Ayling and Ayling 1992a). Grand mean density of coral trout on the five fished reefs was 1.39 fish per transect, almost exactly comparable to the 1.27 recorded from the five reefs that had been protected from fishing for eight years (table 4).

In the previous studies mentioned there was an effect of protection on the length of common coral trout; the mean length of fish was significantly higher on protected reefs than on fished reefs (Ayling et al. 1991). Although mean length of this species was slightly higher on the protected reefs in the present survey the difference was not significant (table 4). Similarly, the results from the present survey did not show a significant increase in the number of recruits and juvenile coral trout <35 cm TL on fished reefs compared to protected reefs that had been demonstrated in previous studies and is thought to be partly responsible for the lack of a detectable fishing effect on the density of this species (table 4).

Table 4. Effect of Protection on the Density and Length of Coral Trout.

Results from mid-shelf reefs only. Density of the various categories is in number per hectare, length is total length in cm. Cairns 91 data from Ayling et al. 1991; Capricorn 86 data from Ayling and Ayling 1986b.

	Density		Recruits		<35 cm		>35 cm		Length	
Area	Fished	Prot.	Fished	Prot.	Fished	Prot.	Fished	Prot.	Fished	Prot.
This survey:										
- baseline	47.4	47.4	5.0	3.6	27.6	22.6	19.0	24.6	33.0	34.3
Cairns 91	45.7	44.7	13.6	7.3	25.9	18.3	19.9	26.4	30.0	35.6
Capricorn 86	49.0	57.0	na	na	26.0	12.0	23.0	45.0	35.7	44.6

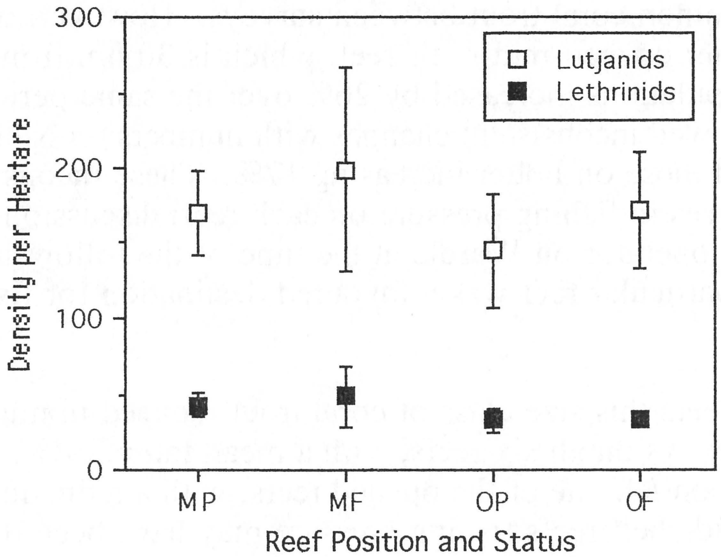
It could be argued that as most of the reefs surveyed in this study were toward the outer edge of the shelf then fishing pressure on the open reefs would not be as great as on reefs closer to the shore and hence a fishing effect might not be expected. However, a fishing effect was not found on mid-shelf reefs off Cairns in the 1991 survey, where reefs are closer to the shore and more assessable to small boat fishermen than in any other area of the GBR. It has also been shown that commercial fishermen take more than half of the coral trout caught in the GBR region (Blamey and Hundloe 1992; Trainor 1991) and their activities are not restricted by distance offshore. It should also be pointed out that the abundance of some lethrinids was apparently affected by fishing on this set of reefs, indicating that fishing pressure was present.

The previous studies mentioned have also looked at the effect of protection on the density of lethrinids and lutjanids. The most important species in these families from the reef fishermen's point of view is the red-throat sweetlip *L. miniatus* (Trainor 1991). The 1986 survey of ten reefs in the Capricorn-Bunker Group, five of which had been protected from fishing for from 2.5-6 years looked at the density of *Lethrinus miniatus* as well as coral trout (Ayling and Ayling 1986b). Density on the protected reefs was almost 3x higher than on the fished reefs (6.5 vs. 2.3 per ha), a difference that was significant (F=16.77, df=1/8, p=0.004). At the same time the density of this species on the back of nine reefs in the Swain Group was 17.3 per ha (Ayling and Ayling 1986b). During a survey in 1991 of Bramble Reef off Lucinda that had reputedly been subject to heavy fishing pressure the density of *L. miniatus* was an order of magnitude lower than on three control reefs (Ayling and Ayling 1992b). Similarly, the baseline survey of the present study found that this species was almost an order of magnitude lower in abundance on the fished mid-shelf reefs compared with the protected reefs in the same category. It is apparent that the density of the red-throat sweetlip *L. miniatus* is markedly affected by fishing pressure and this species should be a prime target for any future surveys.

The surveys on 47 reefs in the Cairns Section in 1991 (Mapstone et al. 1991) did not show any effect of fishing on the total density of lethrinids, either on mid-shelf or outer-shelf reefs (figure 6). The baseline component of the present survey showed similar overall results but there were significantly lower densities of the most abundant species *L. atkinsoni* on fished mid-shelf reefs compared to protected reefs, in addition to the results presented above for *L. miniatus*.

Figure 6. Comparison of Lutjanid and Lethrinid Density on Protected and Fished Reefs in the Cairns Section - Jan-Mar 1991.

Data from survey proposed by Mapstone et al. (1991). Figures shown are grand means per hectare from the combined reefs in each category. MP = mid-shelf protected reefs (n=10); MF = mid-shelf fished reefs (n=16); OP = outer-shelf protected reefs (n=8); OF = outer-shelf fished reefs (n=13). Error bars are standard errors.



In the surveys made to date, including the baseline survey of the present study, protection from fishing has not been shown to have any effect on the density of lutjanids (figures 2, 6). Although all lutjanids are caught by fishermen none of the reef dwelling species are targeted in the way that coral trout and *L. miniatus* are. In addition the two most abundant species, *Lutjanus gibbus* and *L. bohar* are not eaten or sold because of the threat of ciguatera poisoning. One of the lutjanids, the stripey *L. carponotatus*, was significantly more abundant on fished reefs compared with protected reefs in the analyses presented here. However, as has been pointed out, in the surveys made on protected Beaver Reef during the baseline survey that were not incorporated into the analyses, this species was recorded at densities three times those recorded on the two mid-shelf fished reefs. This result is probably an artefact of reef selection.

Effects of Fishing Resumption on Protected Reefs.

As has been pointed out above, coral trout are the most sought after of the targeted species. Fishing pressure is concentrated on fish over the minimum legal limit, which for common coral trout at the time of this study was 35 cm TL. Looking at the effect of fishing resumption on this size class we see that there was a 25% reduction in density on the opened reefs between the baseline survey and the follow-up survey (table 5). However, there was also a 15% reduction on the fished controls and as a result the year x zone interaction was not significant.

It is interesting to look at the mid-shelf reefs individually. Wardle is the more assessable of the opened mid-shelf reefs, being only 23 nautical miles (nm) from the nearest port, and this reef showed a 36% reduction in the density of large common coral trout between surveys. However, on Northeaster, the other opened mid-shelf reef, which is 30 nm from port, large coral trout populations increased by 26% over the same period. The fished reefs also showed inconsistent changes with numbers on Nathan decreasing 20% and those on Potter increasing 17%. These inconsistencies may reflect differences in fishing pressure on each reef; discussions with a fishing charter boat operator on Wardle at the time of the follow-up survey indicated that that particular reef was a favoured destination for fishing parties.

On the outer shelf reefs this size class of coral trout reduced in numbers between the two surveys on all six reefs, with a mean fall of 38%. The fall was highest on Ribbon #4, one of the opened reefs, with a reduction of 72%; as with the mid-shelf reefs fishing pressure may have been different at the reef level.

Fishermen have easier access to the sheltered back reef habitat (NW facing) and fishing pressure may have been greater in this area of the opened reefs. In fact there was a 36% reduction in the density of common coral trout over 35 cm TL on the back of the opened reefs (4% reduction on the front) but only a 9% reduction on the back of the fished controls (27% reduction on the front). This gave a significant habitat x zone x year interaction and may indicate that there was a significant fishing effect on the back of the opened reefs, although the 27% reduction on the front of the fished controls suggests caution in making too much of this.

Table 5. Effect of Fishing Resumption on the Density and Length of Coral Trout.

Results from mid-shelf reefs only. Density of the various categories is in number per hectare, length is mean total length in cm.

Category	Total Trout		Recruits		<35 cm		>35 cm		Length	
Area	Fished	Prot.	Fished	Prot.	Fished	Prot.	Fished	Prot.	Fished	Prot.
Baseline	47.4	47.4	5.0	3.6	27.6	22.6	19.0	24.6	33.0	34.3
Follow-up	42.6	42.6	4.4	3.0	24.6	22.4	18.0	21.4	34.1	34.7

If fishing pressure had increased on the opened reefs then it may be expected that the mean length of coral trout would decrease between the two surveys. In fact there were no significant differences between either reef group or either survey, suggesting that fishing pressure had not had a widespread effect on mean length of coral trout on the opened reefs as a whole (table 5). However, if we confine our attention to the two most assessable of the mid-shelf reefs, Wardle (opened) and Nathan (fished control) we find that during the baseline survey the mean length of common coral trout was 35.4 cm on Wardle (then protected), significantly higher than the 30.7 cm recorded on Nathan (t test: t=2.74, df=159, p=0.007). Twelve months later mean length had reduced on Wardle, while remaining almost the same on Nathan, and there was no significant difference between these two reefs (t=1.386, df=132, p=0.168).

As mentioned above, red-throat sweetlip are apparently significantly reduced in density by fishing pressure. This species was only recorded on the southern mid-shelf reefs as it only occurs very rarely north of Cairns. Analysis of the mid-shelf data showed that although there were significantly higher densities on the protected/opened reefs there was no significant effect on the density of this species caused by the opening of the protected reefs. However, this species is rarely encountered at the scale of counting used for this project (grand mean of 0.11 fish per transect) and the power of the tests was very low (Ayling and Ayling 1992a).

It is interesting to look at the density patterns for this species on the four mid-shelf reefs in more detail (table 6). On the fished reefs at the time of the baseline survey we recorded two individuals in all the counts on Nathan Reef and none on Potter. On the two reefs that had been protected from fishing for eight years we encountered six fish in all the transects on Wardle Reef and ten on Northeaster. Hence, there was a significant, order of magnitude difference in the density of this species between protected and fished reefs. At the time of the follow-up survey, eleven months after the protected reefs had been opened to fishing, this species was still virtually absent on the fished reefs with only a single individual being encountered on Potter. On the opened reefs, we recorded no red-throat sweetlip on the more assessable Wardle Reef but eight individuals on Northeaster. This suggests that, as with the coral trout, Wardle was fished heavily after it was opened but that the more distant Northeaster received very little increase in fishing pressure.

Table 6. Red-Throat Sweetlip Density Patterns.

Mid-shelf reefs only. Density is mean per ha.

Category	Fished		Protected/Opened	
Reef	Nathan	Potter	Wardle	Northeaster
1992	1.4	-	4.0	6.6
1993	-	0.7	-	5.4

Of the other lethrinids, the orange-striped emperor *Lethrinus obsoletus* showed some effects that may indicate an effect of fishing resumption. This species decreased markedly on the back of opened mid-shelf reefs, giving a significant interaction for habitat x shelf position x zone x year. This effect was shown on both Wardle and Northeaster, contradicting the nice story established by the coral trout and red-throat sweetlip.

The lutjanid data from this study confirmed that the reef dwelling members of this group of fishes, in spite of being regularly caught and retained by fishermen, are largely unaffected by fishing pressure. Numbers of the two most abundant species, the paddletail *Lutjanus gibbus* and the red bass *Lutjanus bohar*, increased on the opened reefs and decreased on the fished reefs giving significant year x zone interactions for total lutjanid numbers and paddletails but for the opposite trend to that expected.

All lutjanids are taken by fishermen and in our experience usually retained, but of the species that were common on this survey two are not eaten due to an official ban on sale for fish poisoning reasons (*L. gibbus* and *L. bohar*), while the others are generally too small except for use as bait. Overall there were nominally slightly more lutjanids on fished reefs than on protected reefs but this difference was not significant. Although there were some significant year x zone interactions these were the opposite of what might be expected with an increase in density on the opened reefs.

Many of the species in this family occur as widely scattered large schools that were occasionally encountered during the counts. During the baseline survey such schools were recorded at a single front reef site on Escape, Ribbon #4 and Ruby, and a back reef site on Potter and St. Crispins and this combination was responsible for the interactions reported. More of these schools were observed on outer-shelf reefs than mid-shelf. During the baseline survey there did not appear to be any relationship between number of schools and zone type; three were recorded on fished reefs and two on protected reefs, but in the follow-up survey only one was encountered on fished reefs compared with 4 on the opened reefs (hence the significant year x zone interaction in the 10 reef analysis mentioned above).

In summary, the effects of opening the five formerly protected study reefs to fishing have apparently only been slight and confined to a few species. As might be expected the effects have not been uniformly felt over all five reefs. The common coral trout was reduced in density on the back of a few opened reefs, notably Wardle and Ribbon #4. Red-throat sweetlip were markedly reduced in numbers on Wardle Reef only, while orange-striped emperors decreased in numbers on both opened mid-shelf reefs and also on St. Crispins, one of the outer-shelf fished reefs.

If possible, future surveys of this type should be designed so as to avoid the confounding effect of having shelf position not being balanced in the overall design. As this was the most important factor influencing the abundance of most species, and accounted for a major part of the variance, two of the reefs had to be excluded from the analyses to produce a balanced design that included shelf position.

It would also improve future projects if some estimate of zoning compliance could be made for the closed survey reefs, perhaps by using vessel sighting records from coastwatch and other sources such as QDEH. It would be useful to know if the protected reefs had been subjected to illegal fishing pressure before the zoning was changed and they were opened to fishing. This project would also have been improved if some measure of fishing effort on the reefs both before and after the zoning change could have been made.

Changes in other organisms.

Hard coral cover increased almost 50% between the baseline and follow-up surveys. While we have previously measured annual increases of over 30% in hard coral communities, 50% seems high and may be a result of methodological differences between two sets of observers; while the principal observer was the same for both surveys the assistants responsible for the coral surveys were different. However, soft coral covers were consistent for the two surveys, and the rapid increase in hard coral cover may have been the result of these reefs recovering from cyclone damage caused by Cyclones Ivor and Joy in March and December 1990 respectively. As mentioned above, soft coral cover did not change over the 12 months of this survey, a finding that has been supported by other surveys we have made (Ayling and Ayling 1993). This is in contrast to the established wisdom that suggests soft corals rapidly take over space when hard corals are damaged.

Power of the Tests.

For the report on the baseline survey (Ayling and Ayling 1992a) we calculated the minimum change between fished and protected reefs that could be detected with 90% power with a type I error of 0.1 for a range of species and species groups using the results from the 10 reef analysis. These figures are repeated here (table 7). These power estimations are based on Cohen (1988) and use the effect size index (f) where $f = s_m/s$, where s_m is the standard deviation of the population means and s is the standard deviation within the populations. In this case an estimation of s is provided by the square root of the denominator mean square from the appropriate F test. When site was the denominator $f_{zone}=0.464$ (u=1, n'=21).

Table 7. Minimum Detectable Change with 90% Power.

Minimum detectable difference between fished and protected reefs is expressed as a percentage of the grand mean.

‡ Where site was not significant and tests were made over pooled residual. * Detectable differences assume equal effort to design used. na = not applicable.

Species/Group	Grand mean	Precision	Minimum detectable difference	‡ Minimum detectable difference (pooled ms)
Plectropomus leopardus	1.41	0.42	52%	20%
P. leopardus (mid-shelf) *	2.47	0.24	36%	14%
P. leopardus (back reef) *	1.77	0.40	46%	18%
P. laevis	0.17	0.84	136%	60%
Total Lethrinids	0.99	0.57	122%	na
Lethrinus atkinsoni	0.56	0.69	149%	na
Lethrinus miniatus	0.06	0.74	205%	na
Monotaxis grandoculis	2.52	0.37	80%	na
Total Lutjanids	3.91	0.48	140%	na
Lutjanus gibbus	1.15	0.65	162%	na
Lutjanus bohar	0.94	0.71	210%	na
Total Chaetodontids	12.43	0.17	47%	na
Hard Coral Feeding Chaets	6.54	0.27	57%	na

In addition we looked at the power of the critical year x zone interaction from the analyses presented in this report. The power of this test was extremely poor. We followed the procedure outlined by Cohen (1988) for testing the power of interaction terms. Using site as the denominator and setting a type 1 error of 0.1, it was found that even if mean densities on the opened reefs had been reduced to zero, with those on the fished reefs unchanged, then the power of this interaction would have ranged from 89% for total coral trout, to 39% for total lethrinids to only 26% for red-throat sweetlip on mid-shelf reefs. Even for total chaetodontids it would have needed a reduction in density on the opened reefs of 95% to detect this interaction with a power of 90%. For those few species or groups where site was not significant and the pooled residual could be used power was more acceptable. A 42% reduction in coral trout density on opened reefs would have given a year x zone interaction power of 90% with a type 1 error of 0.1.

Given these low interaction powers it is evident that this type of survey and design is not entirely suitable for a project where the expected result is a density *decrease* for one of the factors. For such a design the maximum change possible is 100% (a reduction to zero), and, with the possible exception of total coral trout, this is not enough to give a reasonable power expectation for most species or groups. On the other hand, for a design where a density *increase* is to be expected, such as on a group of protected reefs, changes of 200-300% are possible (Ayling and Ayling 1994) and this type of design is more appropriate. The best way to increase power for future projects where a density decrease is to be expected would be to increase the number of sites per reef from 6 to 12. This technique has been used in other surveys, such as that looking at the effect of the Bramble Reef replenishment closure (Ayling and Ayling 1994), and increases power, although at the expense of increasing field survey time from one to two days per reef. For the common coral trout, power could be further increased by confining surveys to mid-shelf reefs where this species is more abundant than on outer-shelf reefs.

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ACKNOWLEDGMENTS

Assistance for the baseline survey was provided by Cathy Bone and Warren Nott and for the follow-up survey by Katherine Kelly and Daniel Breen. Terry Ford and Lois Wilson of the charter vessel R.V. Sunbird lightened the load of the field work for the baseline and Bruce Craven and Max of Aurora were a great help on the follow-up. Bruce Mapstone provided advice on analysis. John Robertson helped rush through contracts and payments. Our thanks to all.

APPENDIX 1. DENSITY SUMMARIES FROM THE SURVEYS.

Table i. Summary of Density of Fishing Target Species: Coral Trout 1992.

Figures show means from 50 x 10 m transects from all reefs grouped in various categories with standard deviations in italics.

	P. leopardus		Trout recruits		Trout <35 cm		Trout >35 cm		*P. laevis*	
	mean	st.dev.	mean	st.dev.	mean	st.dev.	mean	st.dev.	mean	st.dev
Fishing Effect										
Fished Reefs	1.39	*1.46*	0.10	*0.34*	0.73	*1.04*	0.65	*1.02*	0.14	*0.38*
Protected Reefs	1.42	*1.52*	0.12	*0.40*	0.66	*1.05*	0.77	*0.96*	0.20	*0.46*
Fished Front	1.12	*1.24*	0.15	*0.43*	0.64	*0.94*	0.45	*0.78*	0.20	*0.46*
Protected Front	0.99	*1.38*	0.14	*0.45*	0.47	*0.96*	0.53	*0.84*	0.17	*0.45*
Fished Back	1.67	*1.61*	0.05	*0.23*	0.81	*1.14*	0.85	*1.18*	0.08	*0.27*
Protected Back	1.85	*1.54*	0.10	*0.34*	0.85	*1.11*	1.00	*1.02*	0.22	*0.48*
Fished Outer Shelf	0.74	*1.15*	-	-	0.29	*0.66*	0.46	*0.77*	0.20	*0.45*
Protected Outer	0.58	*0.89*	0.01	*0.09*	0.16	*0.43*	0.43	*0.72*	0.24	*0.50*
Fished Mid-Shelf	2.37	*1.34*	0.25	*0.51*	1.38	*1.17*	0.95	*1.25*	0.05	*0.22*
Protected Mid	2.54	*1.45*	0.28	*0.56*	1.32	*1.25*	1.22	*1.06*	0.13	*0.40*
Habitat										
Front Reef	1.04	*1.32*	0.14	*0.44*	0.54	*0.95*	0.50	*0.82*	0.18	*0.45*
Back Reef	1.77	*1.57*	0.08	*0.30*	0.83	*1.12*	0.94	*1.09*	0.16	*0.41*
Shelf Position										
Outer Shelf Reefs	0.65	*1.01*	0.00	*0.07*	0.21	*0.54*	0.44	*0.74*	0.22	*0.48*
Mid-Shelf Reefs	2.47	*1.41*	0.27	*0.54*	1.35	*1.22*	1.11	*1.14*	0.10	*0.34*
Outer Shelf Front	0.22	*0.46*	-	-	0.07	*0.25*	0.16	*0.40*	0.27	*0.54*
Outer Shelf Back	1.08	*1.21*	0.01	*0.10*	0.36	*0.70*	0.71	*0.88*	0.18	*0.41*
Mid-Shelf Front	2.20	*1.26*	0.35	*0.63*	1.20	*1.16*	0.97	*1.00*	0.07	*0.25*
Mid-Shelf Back	2.75	*1.50*	0.19	*0.43*	1.49	*1.26*	1.25	*1.26*	0.13	*0.41*
Reef Means										
Wardle	2.70	*1.53*	0.10	*0.31*	1.13	*1.17*	1.57	*1.22*	0.20	*0.48*
Nathan	2.73	*1.44*	0.30	*0.53*	1.67	*1.15*	1.07	*1.44*	0.10	*0.31*
Potter	2.00	*1.14*	0.20	*0.48*	1.10	*1.12*	0.83	*1.05*	-	-
Northeaster	2.03	*1.22*	0.27	*0.52*	1.13	*1.17*	0.90	*0.88*	0.17	*0.46*
Beaver	2.90	*1.49*	0.47	*0.73*	1.70	*1.37*	1.20	*0.96*	0.03	*0.18*
Channel	0.43	*0.77*	-	-	0.13	*0.43*	0.30	*0.65*	0.17	*0.46*
Pellowe	0.43	*0.57*	-	-	0.13	*0.35*	0.3	*0.53*	0.03	*0.18*
St. Crispins	1.50	*1.55*	-	-	0.63	*0.96*	0.87	*1.01*	0.13	*0.35*
Agincourt 3	0.67	*0.92*	0.03	*0.18*	0.10	*0.31*	0.57	*0.77*	0.27	*0.52*
Escape	0.43	*0.77*	-	-	0.07	*0.25*	0.37	*0.76*	0.20	*0.48*
Ruby	0.30	*0.65*	-	-	0.10	*0.31*	0.20	*0.48*	0.43	*0.63*
Ribbon #4	0.77	*1.04*	-	-	0.33	*0.61*	0.47	*0.68*	0.33	*0.55*
Grand Mean	1.41	*1.49*	0.11	*0.37*	0.69	*1.05*	0.72	*0.99*	0.17	*0.43*

Table ii. Summary of Density of Fishing Target Species: Lethrinids 1992.

Figures show means from 50 x 10 m transects grouped in various categories with standard deviations in italics.

	Lethrinidae		*Lethrinus atkinsoni*		*Lethrinus obsoletus*		*Lethrinus miniatus*		*Monotaxis grandoculis*	
	mean	st.dev.	mean	st.dev.	mean	st.dev.	mean	st.dev.	mean	st.dev
Fishing Effect										
Fished Reefs	0.83	*1.35*	0.47	*0.90*	0.16	*0.51*	0.01	*0.16*	2.79	*3.60*
Protected Reefs	1.10	*1.52*	0.63	*1.03*	0.12	*0.42*	0.09	*0.33*	2.32	*2.29*
Fished Front	0.68	*0.97*	0.41	*0.76*	0.03	*0.16*	0.03	*0.23*	2.23	*2.35*
Protected Front	0.91	*1.37*	0.64	*1.07*	0.01	*0.10*	0.08	*0.30*	2.25	*2.52*
Fished Back	0.97	*1.64*	0.53	*1.03*	0.29	*0.67*	-	-	3.36	*4.46*
Protected Back	1.30	*1.64*	0.62	*0.99*	0.23	*0.56*	0.10	*0.36*	2.39	*2.05*
Fished Outer Shelf	1.20	*1.57*	0.72	*1.06*	0.23	*0.62*	-	-	3.50	*4.31*
Protected Outer	1.21	*1.41*	0.75	*1.06*	0.10	*0.42*	-	-	2.98	*2.37*
Fished Mid-Shelf	0.27	*0.58*	0.10	*0.35*	0.05	*0.22*	0.03	*0.26*	1.73	*1.67*
Protected Mid	0.97	*1.65*	0.47	*0.96*	0.14	*0.41*	0.21	*0.49*	1.44	*1.86*
Habitat										
Front Reef	0.82	*1.22*	0.54	*0.95*	0.02	*0.13*	0.06	*0.27*	2.24	*2.44*
Back Reef	1.16	*1.64*	0.58	*1.01*	0.26	*0.61*	0.06	*0.28*	2.79	*3.30*
Shelf Position										
Outer Shelf Reefs	1.20	*1.48*	0.74	*1.06*	0.16	*0.52*	-	-	3.20	*3.34*
Mid-Shelf Reefs	0.69	*1.37*	0.32	*0.80*	0.11	*0.35*	0.14	*0.42*	1.56	*1.79*
Outer Shelf Front	0.94	*1.18*	0.67	*1.01*	-	-	-	-	2.90	*2.75*
Outer Shelf Back	1.47	*1.69*	0.81	*1.11*	0.31	*0.70*	-	-	3.50	*3.83*
Mid-Shelf Front	0.64	*1.27*	0.37	*0.85*	0.04	*0.20*	0.13	*0.41*	1.31	*1.51*
Mid-Shelf Back	0.73	*1.47*	0.27	*0.74*	0.17	*0.45*	0.15	*0.43*	1.81	*2.00*
Reef Means										
Wardle	0.73	*1.01*	0.33	*0.76*	0.20	*0.55*	0.20	*0.48*	1.83	*1.80*
Nathan	0.27	*0.58*	0.07	*0.25*	0.07	*0.25*	0.07	*0.37*	1.50	*1.11*
Potter	0.27	*0.58*	0.13	*0.43*	0.03	*0.18*	-	-	1.97	*2.08*
Northeaster	1.30	*1.84*	0.50	*1.04*	0.17	*0.38*	0.33	*0.55*	2.17	*2.26*
Beaver	0.87	*1.94*	0.57	*1.07*	0.07	*0.25*	0.10	*0.40*	0.33	*0.55*
Channel	1.23	*1.52*	0.77	*1.10*	0.27	*0.69*	-	-	0.93	*1.11*
Pellowe	0.90	*1.16*	0.50	*0.78*	0.20	*0.61*	-	-	2.63	*3.00*
St. Crispins	1.67	*2.06*	1.00	*1.23*	0.43	*0.82*	-	-	4.90	*6.48*
Agincourt 3	0.77	*0.94*	0.47	*0.78*	0.03	*0.18*	-	-	3.17	*1.93*
Escape	1.03	*1.07*	0.73	*1.01*	-	-	-	-	3.57	*1.81*
Ruby	1.03	*1.30*	0.67	*1.09*	0.07	*0.25*	-	-	2.97	*1.67*
Ribbon #4	1.80	*1.79*	1.03	*1.27*	0.10	*0.40*	-	-	4.23	*2.90*
Grand Mean	0.99	*1.45*	0.56	*0.98*	0.14	*0.46*	0.06	*0.28*	2.52	*2.91*

Table iii. Summary of Density of Fishing Target Species: Lutjanids 1992.

Figures show means from 50 x 10 m transects grouped in various categories with standard deviations in italics.

	Lutjanidae		*Lutjanus gibbus*		*Lutjanus bohar*		*Lutjanus quinquelineatus*		*Lutjanus carponotatus*	
	mean	st.dev.	mean	st.dev.	mean	st.dev.	mean	st.dev.	mean	st.dev.
Fishing Effect										
Fished Reefs	4.16	*6.73*	1.18	*3.01*	1.26	*3.75*	0.39	*1.21*	0.31	*0.73*
Protected Reefs	3.74	*4.98*	1.12	*2.17*	0.70	*1.19*	0.44	*1.60*	0.29	*0.73*
Fished Front	4.55	*7.25*	1.09	*1.85*	1.84	*4.74*	0.28	*1.05*	0.27	*0.70*
Protected Front	4.90	*5.93*	1.90	*2.74*	0.79	*1.01*	0.47	*1.56*	0.27	*0.65*
Fished Back	3.77	*6.19*	1.27	*3.85*	0.68	*2.28*	0.51	*1.36*	0.36	*0.76*
Protected Back	2.58	*3.47*	0.34	*0.85*	0.62	*1.34*	0.41	*1.64*	0.30	*0.81*
Fished Outer Shelf	4.61	*7.53*	1.32	*2.57*	1.92	*4.71*	0.04	*0.33*	0.06	*0.27*
Protected Outer	4.56	*5.78*	1.73	*2.62*	0.99	*1.39*	-	-	-	-
Fished Mid-Shelf	3.48	*5.28*	0.97	*3.59*	0.27	*0.61*	0.92	*1.76*	0.70	*1.00*
Protected Mid	2.64	*3.40*	0.32	*0.88*	0.32	*0.68*	1.02	*2.32*	0.67	*1.01*
Habitat										
Front Reef	4.75	*6.49*	1.57	*2.44*	1.23	*3.18*	0.39	*1.37*	0.27	*0.67*
Back Reef	3.08	*4.81*	0.73	*2.60*	0.64	*1.79*	0.45	*1.53*	0.33	*0.79*
Shelf Position										
Outer Shelf Reefs	4.58	*6.57*	1.55	*2.60*	1.39	*3.28*	0.02	*0.22*	0.02	*0.18*
Mid-Shelf Reefs	2.98	*4.25*	0.58	*2.38*	0.30	*0.65*	0.98	*2.11*	0.68	*1.00*
Outer Shelf Front	6.28	*7.84*	2.48	*2.79*	1.79	*4.04*	-	-	0.01	*0.10*
Outer Shelf Back	2.89	*4.42*	0.63	*2.01*	0.99	*2.24*	0.04	*0.31*	0.04	*0.24*
Mid-Shelf Front	2.61	*2.77*	0.29	*0.77*	0.44	*0.76*	0.93	*2.00*	0.63	*0.93*
Mid-Shelf Back	3.35	*5.34*	0.87	*3.26*	0.16	*0.49*	1.03	*2.22*	0.73	*1.07*
Reef Means										
Wardle	1.87	*2.06*	0.47	*1.01*	0.57	*0.82*	0.27	*1.14*	0.20	*0.41*
Nathan	1.47	*1.63*	0.20	*0.48*	0.13	*0.43*	0.10	*0.40*	0.77	*0.90*
Potter	5.50	*6.76*	1.73	*4.98*	0.40	*0.72*	1.73	*2.18*	0.63	*1.10*
Northeaster	1.60	*3.04*	0.40	*1.07*	0.40	*0.77*	0.73	*2.32*	-	-
Beaver	4.47	*4.09*	0.10	*0.40*	-	-	2.07	*2.84*	1.80	*0.96*
Channel	2.23	*3.39*	0.77	*2.13*	0.77	*1.48*	-	-	-	-
Pellowe	3.40	*4.57*	1.07	*2.07*	1.10	*1.71*	0.03	*0.18*	0.07	*0.25*
St. Crispins	3.53	*6.63*	1.40	*3.55*	1.33	*3.24*	0.10	*0.55*	-	-
Agincourt 3	3.63	*3.49*	1.60	*1.94*	1.03	*1.25*	-	-	-	-
Escape	4.63	*5.10*	2.10	*2.55*	1.03	*1.10*	-	-	-	-
Ruby	6.90	*10.1*	1.50	*1.80*	3.33	*7.18*	-	-	0.10	*0.40*
Ribbon #4	7.73	*8.40*	2.43	*3.41*	1.13	*1.70*	-	-	-	-
Grand Mean	3.91	*5.77*	1.15	*2.55*	0.94	*2.60*	0.42	*1.45*	0.30	*0.73*

Table iv. Summary of Density of Chaetodontids and Giant Clams 1992.

Figures show means from 50 x 10 m transects grouped in various categories with standard deviations in italics. Note: Coral Chaets = hard coral feeding chaetodontids.

	Chaetodontids		Coral Chaets		*T. gigas*		*T. derasa*	
	mean	st.dev.	mean	st.dev.	mean	st.dev.	mean	st.dev.
Fishing Effect								
Fished Reefs	12.86	*7.05*	6.45	*5.24*	0.07	*0.31*	0.21	*0.47*
Protected Reefs	12.11	*7.22*	6.60	*5.30*	0.21	*0.51*	0.37	*0.77*
Fished Front	10.84	*4.70*	4.56	*3.17*	0.04	*0.20*	0.12	*0.40*
Protected Front	10.87	*6.67*	4.84	*3.67*	0.14	*0.40*	0.15	*0.41*
Fished Back	14.88	*8.34*	8.33	*6.17*	0.11	*0.39*	0.29	*0.51*
Protected Back	13.36	*7.56*	8.36	*6.05*	0.29	*0.60*	0.58	*0.96*
Fished Outer Shelf	15.30	*7.63*	8.53	*5.63*	0.04	*0.21*	0.14	*0.41*
Protected Outer	15.00	*7.36*	7.93	*5.63*	0.11	*0.38*	0.20	*0.56*
Fished Mid-Shelf	9.20	*3.85*	3.32	*2.23*	0.12	*0.42*	0.30	*0.53*
Protected Mid	8.27	*4.90*	4.83	*4.25*	0.36	*0.62*	0.59	*0.93*
Habitat								
Front Reef	10.86	*5.92*	4.72	*3.47*	0.10	*0.34*	0.14	*0.41*
Back Reef	13.99	*7.91*	8.35	*6.09*	0.21	*0.53*	0.46	*0.81*
Shelf Position								
Outer Shelf Reefs	15.13	*7.46*	8.19	*5.63*	0.08	*0.32*	0.18	*0.50*
Mid-Shelf Reefs	8.64	*4.52*	4.23	*3.65*	0.26	*0.56*	0.47	*0.81*
Outer Shelf Front	12.31	*6.43*	4.90	*3.60*	-	-	0.01	*0.10*
Outer Shelf Back	17.94	*7.38*	11.47	*5.37*	0.16	*0.44*	0.34	*0.66*
Mid-Shelf Front	8.81	*4.41*	4.47	*3.27*	0.24	*0.49*	0.32	*0.57*
Mid-Shelf Back	8.47	*4.65*	3.99	*3.99*	0.28	*0.63*	0.63	*0.97*
Reef Means								
Wardle	8.23	*3.68*	3.87	*2.85*	0.27	*0.74*	0.43	*0.77*
Nathan	7.97	*3.72*	3.67	*2.47*	0.07	*0.25*	0.37	*0.61*
Potter	10.43	*3.64*	2.97	*1.94*	0.17	*0.53*	0.23	*0.43*
Northeaster	5.77	*3.18*	2.67	*2.50*	0.27	*0.45*	0.90	*1.27*
Beaver	10.8	*6.07*	7.97	*5.01*	0.53	*0.63*	0.43	*0.57*
Channel	9.03	*5.22*	4.17	*3.88*	0.10	*0.31*	-	-
Pellowe	14.90	*8.86*	8.47	*7.01*	0.03	*0.18*	-	-
St. Crispins	16.50	*7.99*	8.17	*5.06*	0.03	*0.18*	0.20	*0.48*
Agincourt 3	19.13	*7.83*	11.47	*7.15*	0.03	*0.18*	0.07	*0.25*
Escape	15.40	*6.38*	8.23	*4.59*	0.23	*0.63*	0.33	*0.71*
Ruby	14.50	*5.84*	8.97	*4.72*	0.07	*0.25*	0.23	*0.50*
Ribbon #4	16.43	*6.02*	7.83	*3.89*	0.07	*0.25*	0.40	*0.77*
Grand Mean	12.43	*7.15*	6.54	*5.27*	0.16	*0.45*	0.30	*0.66*

Table v. Summary of Density of Prey Species: Pomacentrids 1992.

Figures show means from 20 x 2.5 m transects grouped in various categories with standard deviations in italics. *Pom. molluc.* = *Pomacentrus molluccensis*, *Ambly.* = *Amblyglyphidodon curacao*, *Chrysiptera* = *C. rollandi*, *Pl. lacry.* = *Plectroglyphidodon lacrymatus*, *Pl. dicki* = *Plectroglyphidodon dicki*.

	Pom. molluc.		*Ambly.*		*Chrysiptera*		*Pl. lacry.*		*Pl. dicki*	
	mean	st.dev.	mean	st.dev.	mean	st.dev.	mean	st.dev.	mean	st.dev
Fishing Effect										
Fished Reefs	8.6	*11.7*	1.42	*2.51*	2.79	*5.00*	2.79	*4.48*	0.75	*2.05*
Protected Reefs	12.6	*25.6*	1.55	*2.54*	2.08	*4.52*	4.03	*5.58*	0.54	*1.56*
Fished Front	3.1	*7.5*	0.87	*2.81*	0.41	*1.50*	4.08	*5.60*	1.44	*2.71*
Protected Front	5.8	*13.8*	0.99	*2.27*	0.43	*1.71*	3.92	*6.00*	1.05	*2.06*
Fished Back	14.0	*12.7*	1.97	*2.05*	5.17	*6.05*	1.87	*2.56*	0.05	*0.32*
Protected Back	19.4	*32.2*	2.11	*2.68*	3.73	*5.71*	4.13	*5.15*	0.04	*0.31*
Fished Outer Shelf	6.6	*11.9*	0.74	*1.30*	1.50	*3.91*	2.36	*3.96*	1.23	*2.53*
Protected Outer	5.1	*8.6*	0.69	*1.54*	1.06	*2.20*	4.48	*5.50*	0.88	*1.94*
Fished Mid-Shelf	11.4	*10.9*	2.43	*3.41*	4.73	*5.81*	3.90	*5.05*	0.02	*0.13*
Protected Mid	22.7	*35.5*	2.70	*3.10*	3.44	*6.18*	3.43	*5.65*	0.10	*0.54*
Habitat										
Front Reef	4.7	*11.7*	0.94	*2.50*	0.42	*1.62*	3.99	*5.82*	1.21	*2.36*
Back Reef	17.2	*26.0*	2.06	*2.43*	4.33	*5.89*	3.19	*4.40*	0.04	*0.31*
Shelf Position										
Outer Shelf Reefs	5.7	*10.2*	0.71	*1.44*	1.25	*3.05*	3.57	*5.01*	1.03	*2.22*
Mid-Shelf Reefs	18.2	*28.8*	2.59	*3.22*	3.96	*6.05*	3.62	*5.40*	0.07	*0.43*
Outer Shelf Front	-	-	-	-	-	-	3.22	*5.41*	1.98	*2.80*
Outer Shelf Back	11.5	*11.9*	1.43	*1.78*	2.50	*3.95*	3.91	*4.57*	0.08	*0.41*
Mid-Shelf Front	11.2	*15.9*	2.25	*3.48*	1.01	*2.40*	5.07	*6.23*	0.13	*0.60*
Mid-Shelf Back	25.1	*36.4*	2.93	*2.91*	6.91	*7.10*	2.17	*3.97*	-	-
Reef Means										
Wardle	6.1	*7.0*	2.17	*3.06*	0.93	*1.70*	9.17	*6.47*	0.03	*0.18*
Nathan	10.7	*9.7*	2.63	*4.33*	3.80	*4.15*	4.77	*5.42*	-	-
Potter	12.1	*12.2*	2.23	*2.19*	5.67	*7.04*	3.03	*4.57*	0.03	*0.18*
Northeaster	6.5	*6.6*	3.03	*3.13*	1.30	*2.60*	1.13	*2.10*	0.27	*0.91*
Beaver	55.4	*46.0*	2.90	*3.13*	8.10	*8.60*	-	-	-	-
Channel	3.3	*5.2*	0.60	*1.07*	0.67	*1.52*	3.13	*4.24*	0.37	*1.22*
Pellowe	2.5	*3.4*	0.63	*0.89*	0.30	*0.92*	1.77	*2.28*	0.67	*1.67*
St. Crispins	13.5	*17.5*	0.87	*1.53*	3.63	*6.10*	2.63	*4.06*	0.83	*1.93*
Agincourt 3	7.2	*10.3*	0.7	*0.99*	1.30	*2.53*	4.77	*5.56*	1.50	*2.66*
Escape	6.5	*11.5*	1.00	*2.51*	1.17	*2.45*	5.73	*6.78*	0.87	*1.61*
Ruby	3.9	*6.5*	0.73	*1.44*	0.57	*1.36*	2.67	*5.10*	2.20	*3.42*
Ribbon #4	3.3	*5.2*	0.47	*1.11*	1.10	*2.22*	4.27	*5.08*	0.77	*1.91*
Grand Mean	10.9	*21.0*	1.50	*2.52*	2.38	*4.73*	3.59	*5.17*	0.63	*1.78*

Table vi. Summary of Cover of Encrusting Organisms and *Drupella* Damage 1992.

Figures show means from 20 m line intersect transects for the cover of encrusting organisms, from 30 x 1 m transects for coral colony density, and the percentage of coral colonies damaged by *Drupella* grazing in 30 x 1 m transects, grouped in various categories with standard deviations in italics.

	% Hard coral		% Soft coral		Coral colonies		*Drupella* damage	
	mean	st.dev.	mean	st.dev.	mean	st.dev.	mean	st.dev.
Fishing Effect								
Fished Reefs	17.7	*12.2*	15.7	*13.5*	80.8	*57.7*	0.21	*0.47*
Protected Reefs	20.6	*13.0*	9.60	*11.4*	95.6	*61.6*	0.37	*0.77*
Fished Front	15.7	*8.72*	15.2	*12.4*	101.4	*72.2*	0.12	*0.40*
Protected Front	20.0	*12.2*	12.1	*13.2*	119.0	*74.0*	0.15	*0.41*
Fished Back	19.7	*14.6*	16.1	*14.5*	60.2	*24.7*	0.29	*0.51*
Protected Back	21.1	*13.9*	7.1	*8.7*	72.2	*32.4*	0.58	*0.96*
Fished Outer Shelf	22.4	*12.9*	13.4	*14.6*	88.2	*66.3*	0.14	*0.41*
Protected Outer	23.1	*13.2*	6.6	*9.4*	107.7	*68.7*	0.20	*0.56*
Fished Mid-Shelf	10.6	*6.2*	19.1	*10.7*	69.6	*39.4*	0.30	*0.53*
Protected Mid	17.2	*12.1*	13.6	*12.7*	79.5	*46.3*	0.59	*0.93*
Habitat								
Front Reef	18.2	*11.1*	13.4	*13.0*	111.7	*73.6*	0.14	*0.41*
Back Reef	20.5	*14.1*	10.8	*12.3*	67.2	*30.0*	0.46	*0.81*
Shelf Position								
Outer Shelf Reefs	22.8	*13.0*	9.5	*12.3*	99.4	*68.2*	0.18	*0.50*
Mid-Shelf Reefs	14.6	*10.7*	15.8	*12.2*	75.5	*43.8*	0.47	*0.81*
Outer Shelf Front	19.4	*10.5*	10.3	*11.8*	125.3	*85.6*	0.01	*0.10*
Outer Shelf Back	26.2	*14.3*	8.7	*12.9*	73.5	*26.0*	0.34	*0.66*
Mid-Shelf Front	16.5	*11.6*	17.8	*13.3*	92.6	*46.7*	0.32	*0.57*
Mid-Shelf Back	12.6	*9.2*	13.9	*10.7*	58.4	*33.0*	0.63	*0.97*
Reef Means								
Wardle	13.8	*7.7*	21.2	*15.3*	97.8	*36.1*	0.77	*0.93*
Nathan	10.2	*5.2*	17.7	*9.4*	61.6	*23.2*	1.72	*2.51*
Potter	11.0	*7.1*	20.5	*11.9*	77.6	*49.8*	1.12	*2.17*
Northeaster	15.0	*12.2*	9.5	*9.3*	46.1	*31.9*	2.04	*4.28*
Beaver	22.8	*14.0*	10.3	*9.2*	94.6	*50.2*	2.0	*2.73*
Channel	14.6	*12.1*	6.4	*9.5*	54.8	*31.3*	3.11	*3.51*
Pellowe	21.6	*16.4*	18.2	*18.6*	49.6	*25.8*	2.57	*2.63*
St. Crispins	22.4	*13.6*	14.8	*12.9*	71.6	*30.5*	4.17	*3.48*
Agincourt 3	30.6	*12.9*	5.0	*9.9*	105.4	*43.6*	3.50	*3.32*
Escape	24.9	*13.0*	6.0	*7.1*	117.8	*68.8*	3.36	*3.63*
Ruby	23.2	*7.1*	7.1	*8.9*	143.6	*83.1*	4.04	*3.90*
Ribbon #4	22.2	*9.4*	8.9	*10.6*	153.0	*81.3*	1.94	*2.27*
Grand Mean	19.4	*12.7*	12.1	*12.7*	89.4	*60.4*	2.53	*3.21*

Table vii. Summary of Density of Fishing Target Species: Coral Trout 1993.

Figures show means from 50 x 10 m transects from all reefs grouped in various categories with standard deviations in italics.

	P. leopardus		Trout recruits		Trout <35 cm		Trout >35 cm		*P. laevis*	
	mean	st.dev.	mean	st.dev.	mean	st.dev.	mean	st.dev.	mean	st.dev
Fishing Effect										
Fished Reefs	1.15	*1.38*	0.10	*0.38*	0.60	*0.94*	0.55	*0.92*	0.19	*0.47*
Protected Reefs	1.00	*1.31*	0.07	*0.28*	0.48	*0.88*	0.54	*0.81*	0.29	*0.56*
Fished Front	0.85	*1.35*	0.04	*0.20*	0.52	*0.98*	0.33	*0.72*	0.21	*0.44*
Protected Front	0.77	*1.24*	0.04	*0.20*	0.35	*0.67*	0.47	*0.79*	0.25	*0.50*
Fished Back	1.45	*1.36*	0.16	*0.49*	0.68	*0.90*	0.77	*1.05*	0.17	*0.50*
Protected Back	1.23	*1.35*	0.09	*0.34*	0.61	*1.04*	0.61	*0.82*	0.33	*0.62*
Fished Outer Shelf	0.50	*0.94*	0.02	*0.15*	0.18	*0.46*	0.32	*0.82*	0.23	*0.54*
Protected Outer	0.26	*0.54*	0.01	*0.11*	0.06	*0.28*	0.20	*0.46*	0.35	*0.57*
Fished Mid-Shelf	2.13	*1.37*	0.22	*0.56*	1.23	*1.11*	0.90	*0.97*	0.13	*0.34*
Protected Mid	2.13	*1.32*	0.15	*0.40*	1.12	*1.08*	1.07	*0.94*	0.23	*0.56*
Habitat										
Front Reef	0.81	*1.29*	0.04	*0.20*	0.43	*0.84*	0.40	*0.76*	0.23	*0.47*
Back Reef	1.34	*1.36*	0.13	*0.42*	0.65	*0.97*	0.69	*0.94*	0.25	*0.57*
Shelf Position										
Outer Shelf Reefs	0.37	*0.77*	0.02	*0.13*	0.12	*0.39*	0.26	*0.66*	0.28	*0.55*
Mid-Shelf Reefs	2.13	*1.34*	0.18	*0.48*	1.18	*1.09*	0.98	*0.95*	0.18	*0.47*
Outer Shelf Front	0.03	*0.18*	-	-	0.01	*0.11*	0.02	*0.15*	0.29	*0.52*
Outer Shelf Back	0.71	*0.96*	0.03	*0.18*	0.22	*0.51*	0.49	*0.86*	0.28	*0.58*
Mid-Shelf Front	1.98	*1.36*	0.10	*0.30*	1.07	*1.04*	0.97	*0.94*	0.15	*0.36*
Mid-Shelf Back	2.28	*1.32*	0.27	*0.61*	1.28	*1.14*	1.00	*0.97*	0.22	*0.56*
Reef Means										
Wardle	2.07	*1.14*	0.13	*0.35*	1.07	*0.94*	1.00	*0.74*	0.33	*0.71*
Nathan	2.40	*1.43*	0.33	*0.71*	1.57	*1.17*	0.83	*0.95*	0.13	*0.35*
Potter	1.87	*1.28*	0.10	*0.31*	0.90	*0.96*	0.97	*1.00*	0.13	*0.35*
Northeaster	2.20	*1.49*	0.17	*0.46*	1.17	*1.21*	1.13	*1.11*	0.13	*0.35*
Channel	0.13	*0.35*	-	-	-	-	0.13	*0.35*	0.13	*0.35*
Pellowe	0.20	*0.41*	-	-	-	-	0.20	*0.41*	0.20	*0.41*
St. Crispins	0.93	*1.34*	0.03	*0.18*	0.27	*0.58*	0.67	*1.27*	0.07	*0.25*
Escape	0.47	*0.73*	0.03	*0.18*	0.17	*0.46*	0.30	*0.60*	0.30	*0.47*
Ruby	0.37	*0.67*	0.03	*0.18*	0.27	*0.52*	0.10	*0.31*	0.43	*0.77*
Ribbon #4	0.13	*0.35*	-	-	-	-	0.13	*0.35*	0.57	*0.73*
Grand Mean	1.08	*1.35*	0.08	*0.33*	0.54	*0.91*	0.55	*0.87*	0.24	*0.52*

Table viii. Summary of Density of Fishing Target Species: Lethrinids 1993.

Figures show means from 50 x 10 m transects grouped in various categories with standard deviations in italics.

	Lethrinidae		*Lethrinus atkinsoni*		*Lethrinus obsoletus*		*Lethrinus miniatus*		*Monotaxis grandoculis*	
	mean	st.dev.	mean	st.dev.	mean	st.dev.	mean	st.dev.	mean	st.dev
Fishing Effect										
Fished Reefs	0.85	*1.72*	0.64	*1.56*	0.04	*0.20*	0.01	*0.08*	2.15	*2.65*
Protected Reefs	0.86	*1.14*	0.44	*0.89*	0.13	*0.38*	0.05	*0.25*	2.55	*2.30*
Fished Front	0.95	*2.03*	0.84	*2.01*	-	-	0.01	*0.12*	1.77	*1.86*
Protected Front	0.87	*1.18*	0.47	*0.99*	0.03	*0.16*	0.09	*0.34*	2.04	*1.96*
Fished Back	0.76	*1.34*	0.44	*0.86*	0.08	*0.27*	-	-	2.53	*3.22*
Protected Back	0.85	*1.11*	0.41	*0.79*	0.24	*0.49*	0.01	*0.12*	3.05	*2.51*
Fished Outer Shelf	1.22	*1.97*	1.02	*1.91*	0.07	*0.25*	-	-	2.40	*2.02*
Protected Outer	1.22	*1.28*	0.66	*1.06*	0.19	*0.45*	-	-	3.08	*2.49*
Fished Mid-Shelf	0.30	*1.05*	0.07	*0.25*	-	-	0.02	*0.13*	1.78	*1.94*
Protected Mid	0.35	*0.63*	0.10	*0.30*	0.07	*0.25*	0.13	*0.39*	1.95	*1.85*
Habitat										
Front Reef	0.91	*1.66*	0.65	*1.59*	0.01	*0.12*	0.05	*0.25*	1.91	*1.90*
Back Reef	0.81	*1.23*	0.43	*0.82*	0.16	*0.40*	0.01	*0.08*	2.79	*2.89*
Shelf Position										
Outer Shelf Reefs	1.21	*1.65*	0.84	*1.55*	0.12	*0.36*	-	-	2.67	*2.77*
Mid-Shelf Reefs	0.33	*0.86*	0.08	*0.28*	0.03	*0.18*	0.08	*0.29*	1.87	*1.89*
Outer Shelf Front	1.29	*1.97*	1.02	*1.96*	-	-	-	-	2.04	*1.95*
Outer Shelf Back	1.13	*1.26*	0.67	*0.97*	0.24	*0.48*	-	-	3.30	*3.29*
Mid-Shelf Front	0.33	*0.71*	0.10	*0.30*	0.03	*0.18*	0.13	*0.39*	1.70	*1.83*
Mid-Shelf Back	0.32	*1.00*	0.07	*0.25*	0.03	*0.18*	0.02	*0.13*	2.03	*1.95*
Reef Means										
Wardle	0.20	*0.41*	0.07	*0.25*	0.10	*0.31*	-	-	1.90	*1.69*
Nathan	0.10	*0.31*	0.07	*0.25*	-	-	-	-	1.43	*1.33*
Potter	0.50	*1.43*	0.07	*0.25*	-	-	0.03	*0.18*	2.13	*2.37*
Northeaster	0.50	*0.78*	0.13	*0.35*	0.03	*0.18*	0.27	*0.52*	2.00	*2.02*
Channel	0.90	*1.06*	0.60	*0.93*	0.10	*0.31*	-	-	1.57	*1.79*
Pellowe	1.07	*1.08*	0.93	*1.05*	0.10	*0.31*	-	-	1.93	*1.95*
St. Crispins	1.57	*2.99*	1.37	*2.94*	0.03	*0.18*	-	-	2.63	*4.48*
Escape	1.10	*1.37*	0.70	*1.26*	0.30	*0.60*	-	-	2.70	*1.62*
Ruby	1.03	*1.27*	0.77	*1.10*	0.07	*0.25*	-	-	2.63	*1.92*
Ribbon #4	1.60	*1.30*	0.70	*1.02*	0.13	*0.35*	-	-	4.57	*2.91*
Grand Mean	0.86	*1.46*	0.54	*1.27*	0.09	*0.30*	0.19	*2.35*	2.48	*2.91*

Table ix. Summary of Density of Fishing Target Species: Lutjanids 1993.

Figures show means from 50 x 10 m transects grouped in various categories with standard deviations in italics.

	Lutjanidae		*Lutjanus gibbus*		*Lutjanus bohar*		*Lutjanus quinquelineatus*		*Lutjanus carponotatus*	
	mean	st.dev.	mean	st.dev.	mean	st.dev.	mean	st.dev.	mean	st.dev.
Fishing Effect										
Fished Reefs	2.39	*3.67*	0.71	*1.22*	0.84	*2.16*	0.45	*3.14*	0.24	*0.59*
Protected Reefs	3.75	*5.59*	1.77	*3.37*	1.11	*2.81*	0.12	*0.80*	0.03	*0.16*
Fished Front	2.03	*2.65*	0.93	*1.46*	0.89	*3.37*	0.23	*1.12*	0.12	*0.43*
Protected Front	5.69	*6.23*	3.08	*4.31*	1.32	*2.11*	0.01	*0.12*	0.03	*0.16*
Fished Back	2.75	*4.45*	0.49	*0.86*	0.79	*2.50*	0.88	*4.41*	0.36	*0.69*
Protected Back	1.80	*4.05*	0.45	*0.86*	0.89	*3.37*	0.23	*1.12*	0.03	*0.16*
Fished Outer Shelf	2.36	*3.44*	1.04	*1.40*	1.12	*2.64*	-	-	0.03	*0.18*
Protected Outer	4.88	*6.65*	2.76	*4.17*	1.53	*3.59*	0.01	*0.11*	0.01	*0.11*
Fished Mid-Shelf	2.43	*4.01*	0.22	*0.61*	0.42	*0.98*	1.13	*4.91*	0.55	*0.81*
Protected Mid	2.38	*3.40*	0.45	*0.75*	0.58	*1.00*	0.28	*1.25*	0.05	*0.22*
Habitat										
Front Reef	3.86	*5.11*	2.01	*3.39*	1.11	*1.95*	0.02	*0.14*	0.07	*0.33*
Back Reef	2.27	*4.27*	0.47	*0.86*	0.84	*2.96*	0.55	*3.22*	0.19	*0.53*
Shelf Position										
Outer Shelf Reefs	3.51	*5.33*	1.84	*3.15*	1.29	*3.10*	0.01	*0.07*	0.02	*0.15*
Mid-Shelf Reefs	2.41	*3.70*	0.33	*0.69*	0.50	*0.99*	0.71	*3.59*	0.30	*0.64*
Outer Shelf Front	4.81	*5.81*	3.00	*4.03*	1.34	*2.29*	-	-	-	-
Outer Shelf Back	2.20	*4.46*	0.69	*1.01*	1.23	*3.75*	0.01	*0.11*	0.04	*0.21*
Mid-Shelf Front	2.43	*3.41*	0.52	*0.87*	0.75	*1.23*	0.05	*0.22*	0.18	*0.50*
Mid-Shelf Back	2.38	*4.00*	0.15	*0.36*	0.25	*0.57*	1.37	*5.01*	0.42	*0.74*
Reef Means										
Wardle	3.37	*4.20*	0.53	*0.94*	0.73	*1.01*	-	-	0.10	*0.31*
Nathan	0.93	*1.23*	0.07	*0.25*	0.20	*0.66*	-	-	0.43	*0.82*
Potter	3.93	*5.15*	0.37	*0.81*	0.63	*1.19*	2.27	*6.81*	0.67	*0.80*
Northeaster	1.40	*1.98*	0.37	*0.49*	0.43	*0.97*	0.57	*1.74*	-	-
Channel	2.13	*3.86*	1.60	*3.37*	0.47	*1.17*	0.03	*0.18*	0.03	*0.18*
Pellowe	1.27	*2.03*	0.77	*1.43*	0.53	*0.82*	-	-	-	-
St. Crispins	1.90	*3.84*	0.53	*0.94*	1.27	*3.67*	-	-	0.07	*0.25*
Escape	2.90	*3.16*	1.80	*1.88*	0.77	*1.04*	-	-	-	-
Ruby	3.90	*3.68*	1.83	*1.44*	1.57	*2.60*	-	-	0.03	*0.18*
Ribbon #4	8.93	*8.79*	4.53	*5.54*	3.13	*5.54*	-	-	-	-
Grand Mean	3.07	*4.77*	1.24	*2.58*	0.97	*2.51*	0.29	*2.29*	0.13	*0.44*

Table x. Summary of Density of Chaetodontids and Encrusting Organisms 1993.

Figures show means from 50 x 10 m transects for the chaetodontids, and from 20 m line intersect transects for the cover of encrusting organisms, grouped in various categories with standard deviations in italics. Note: Coral Chaets = hard coral feeding chaetodontids.

	Chaetodontids		Coral Chaets		% Hard Coral		% Soft Coral	
	mean	st.dev.	mean	st.dev.	mean	st.dev.	mean	st.dev.
Fishing Effect								
Fished Reefs	12.12	*5.70*	6.36	*4.44*	26.8	*13.9*	18.1	*15.3*
Protected Reefs	12.66	*6.36*	6.93	*4.71*	26.4	*14.1*	11.4	*10.6*
Fished Front	10.87	*4.59*	4.43	*2.81*	24.7	*11.5*	18.1	*16.0*
Protected Front	12.33	*5.69*	6.33	*4.77*	26.1	*14.5*	13.2	*12.9*
Fished Back	13.37	*6.42*	8.29	*4.93*	29.0	*15.8*	18.0	*14.7*
Protected Back	12.99	*7.00*	7.53	*4.60*	26.7	*13.9*	9.6	*7.4*
Fished Outer Shelf	14.67	*5.24*	7.67	*4.87*	30.1	*15.0*	15.1	*16.1*
Protected Outer	15.60	*6.23*	8.82	*5.03*	31.2	*14.8*	6.9	*8.0*
Fished Mid-Shelf	8.30	*4.00*	4.40	*2.76*	22.0	*10.5*	22.5	*12.9*
Protected Mid	8.50	*4.10*	4.50	*2.81*	20.9	*10.1*	18.6	*10.1*
Habitat								
Front Reef	11.60	*5.20*	5.38	*4.02*	25.4	*13.0*	15.6	*14.7*
Back Reef	13.18	*6.70*	7.91	*4.77*	27.8	*14.9*	13.8	*12.3*
Shelf Position								
Outer Shelf Reefs	15.05	*5.68*	8.11	*4.95*	30.0	*15.1*	10.8	*13.3*
Mid-Shelf Reefs	8.64	*4.52*	4.23	*3.65*	0.26	*0.56*	0.47	*0.81*
Outer Shelf Front	13.27	*5.30*	5.94	*4.68*	26.1	*14.7*	12.1	*15.7*
Outer Shelf Back	16.83	*5.52*	10.28	*4.24*	34.0	*14.5*	9.6	*10.4*
Mid-Shelf Front	9.10	*3.91*	4.53	*2.55*	24.3	*10.1*	20.9	*11.1*
Mid-Shelf Back	7.70	*4.06*	4.37	*3.00*	18.6	*9.7*	20.2	*12.3*
Reef Means								
Wardle	8.53	*4.07*	4.10	*3.11*	23.8	*9.1*	20.4	*8.3*
Nathan	7.03	*3.21*	3.43	*2.21*	18.1	*9.8*	20.6	*9.4*
Potter	9.57	*4.34*	5.37	*2.95*	25.8	*9.8*	24.4	*15.6*
Northeaster	8.47	*4.19*	4.90	*2.47*	18.1	*10.3*	16.8	*11.5*
Channel	11.87	*5.44*	5.17	*4.18*	18.3	*10.5*	7.4	*7.1*
Pellowe	13.63	*4.59*	7.07	*5.17*	26.5	*16.6*	14.0	*14.9*
St. Crispins	13.53	*5.04*	6.17	*4.23*	29.7	*16.5*	24.2	*19.4*
Escape	15.20	*4.73*	8.70	*4.10*	37.4	*15.1*	4.0	*5.4*
Ruby	16.83	*5.53*	9.77	*4.56*	34.0	*10.7*	7.2	*6.5*
Ribbon #4	19.23	*5.84*	11.80	*4.53*	34.4	*12.6*	8.3	*10.1*
Grand Mean	12.39	*6.04*	6.65	*4.58*	26.6	*14.0*	14.7	*13.6*

Table xi. Summary of Density of Prey Species: Pomacentrids 1993.

Figures show means from 20 x 2.5 m transects grouped in various categories with standard deviations in italics. *Pom. molluc. = Pomacentrus molluccensis, Ambly. = Amblyglyphidodon curacao, Chrysiptera = C. rollandi, Pl. lacry. = Plectroglyphidodon lacrymatus, Pl. dicki = Plectroglyphidodon dicki.*

	Pom. molluc.		*Ambly.*		*Chrysiptera*		*Pl. lacry.*		*Pl. dicki*	
	mean	st.dev.	mean	st.dev.	mean	st.dev.	mean	st.dev.	mean	st.dev
Fishing Effect										
Fished Reefs	9.31	*13.11*	1.70	*2.19*	2.34	*3.41*	3.07	*4.80*	0.45	*1.38*
Protected Reefs	4.55	*7.21*	1.82	*3.88*	1.45	*2.62*	3.91	*4.80*	0.81	*2.05*
Fished Front	3.60	*7.76*	0.68	*1.48*	0.99	*2.46*	2.89	*4.15*	0.84	*1.85*
Protected Front	1.60	*4.61*	1.51	*4.87*	0.17	*0.81*	3.12	*1.30*	1.61	*2.67*
Fished Back	15.0	*14.8*	2.72	*2.32*	3.69	*3.69*	3.25	*5.40*	0.07	*0.38*
Protected Back	7.51	*8.11*	2.13	*2.55*	2.72	*3.13*	4.71	*5.15*	-	-
Fished Outer Shelf	3.52	*6.90*	1.38	*2.15*	1.13	*2.08*	3.99	*5.68*	0.69	*1.63*
Protected Outer	2.41	*4.00*	1.01	*1.98*	1.29	*2.66*	4.22	*5.26*	1.36	*2.57*
Fished Mid-Shelf	18.0	*15.3*	2.18	*2.17*	4.15	*4.15*	1.70	*2.53*	0.10	*0.77*
Protected Mid	7.97	*9.39*	3.12	*5.44*	1.78	*2.62*	3.80	*4.15*	0.08	*0.38*
Habitat										
Front Reef	2.60	*6.44*	1.09	*3.61*	0.58	*1.87*	3.01	*4.21*	1.23	*2.32*
Back Reef	11.3	*12.5*	2.43	*2.44*	3.21	*3.45*	3.98	*5.31*	0.03	*0.27*
Shelf Position										
Outer Shelf Reefs	2.90	*5.63*	1.17	*2.05*	1.18	*2.35*	3.99	*5.43*	0.99	*2.14*
Mid-Shelf Reefs	13.0	*13.6*	2.65	*4.15*	2.97	*3.66*	2.75	*3.58*	0.09	*0.61*
Outer Shelf Front	-	-	0.06	*0.31*	-	-	2.77	*4.35*	1.92	*2.70*
Outer Shelf Back	5.80	*6.84*	2.28	*2.43*	2.36	*2.88*	5.21	*6.12*	0.06	*0.35*
Mid-Shelf Front	6.50	*8.89*	2.65	*5.35*	1.45	*2.75*	3.37	*4.01*	0.18	*0.85*
Mid-Shelf Back	19.5	*14.5*	2.65	*2.48*	4.48	*3.83*	2.13	*3.00*	-	-
Reef Means										
Wardle	7.50	*7.33*	1.13	*1.33*	1.87	*2.67*	5.10	*4.78*	0.17	*0.53*
Nathan	15.6	*11.3*	1.87	*1.98*	3.77	*2.81*	1.77	*2.47*	-	-
Potter	20.4	*18.4*	2.50	*2.35*	4.53	*5.18*	1.63	*2.62*	0.20	*1.10*
Northeaster	8.43	*11.2*	5.10	*7.09*	1.70	*2.61*	2.50	*2.96*	-	-
Channel	1.10	*2.06*	0.90	*1.65*	0.30	*1.12*	4.60	*6.12*	-	-
Pellowe	1.53	*2.79*	0.93	*1.51*	0.73	*1.51*	3.37	*5.28*	0.13	*0.57*
St. Crispins	5.60	*9.89*	2.07	*2.90*	2.03	*2.87*	3.77	*5.32*	0.10	*0.31*
Escape	3.80	*5.17*	1.00	*2.27*	1.43	*2.71*	2.17	*3.27*	2.37	*3.24*
Ruby	3.43	*5.64*	1.13	*1.68*	0.63	*1.25*	4.83	*6.45*	1.83	*2.39*
Ribbon #4	1.93	*3.53*	0.97	*1.90*	1.93	*3.27*	5.20	*5.44*	1.50	*2.45*
Grand Mean	6.93	*10.8*	1.76	*3.15*	1.89	*3.06*	3.49	*4.81*	0.63	*1.75*

APPENDIX 2. WIDTH ESTIMATION FOR EACH TRANSECT.

Reef/Site	#1	#2	#3	#4	#5	Mean	Reef mean	
Wardle							9.89	
Site 1	9.9	10.7	10.1	9.2	9.6	9.9		**Grand Mean**
Site 2	8.9	9.7	9.1	12.3	10.2	10.04		**9.99**
Site 3	9.3	11.2	9.3	10.1	9.2	9.82		**Std. Dev.**
Site 4	9.6	10.5	8.5	10.1	10.6	9.86		**0.71**
Site 5	9.7	10.7	10.1	9.3	9.4	9.84		**Max. Est.**
Site 6	9.4	11.2	9.9	8.7	10.3	9.9		**12.30**
Nathan							9.90	**Min. Est.**
Site 1	9.9	9.9	9.3	9.5	9.4	9.6		**8.30**
Site 2	9.5	10.5	10	9.6	9.9	9.9		
Site 3	10.6	9.2	11.5	9.3	8.6	9.84		
Site 4	9.5	11.5	9.7	9.8	11.1	10.32		
Site 5	10.4	10.4	9.1	10	9.4	9.86		
Site 6	9.1	9.2	9.7	10.8	10.7	9.9		
Potter							10.00	
Site 1	10.1	10	9.7	10.6	10	10.08		
Site 2	9.9	10	9.9	10	9.5	9.86		
Site 3	10.6	9.9	10.8	10.4	10.3	10.4		
Site 4	10	10.6	10.4	9	9.5	9.9		
Site 5	8.9	11.7	10.6	9.4	9.1	9.94		
Site 6	9.9	10.4	8.7	9.2	10.9	9.82		
North Easter							10.17	
Site 1	11.1	10.2	9.9	10.4	10.1	10.34		
Site 2	9.8	10.5	10.8	10	9.9	10.2		
Site 3	11.5	10.7	11.2	10	9.8	10.64		
Site 4	9.7	9.4	10	9.1	11.2	9.88		
Site 5	9.3	10.8	9.8	9.6	10.4	9.98		
Site 6	9.3	10	10.5	10.1	9.9	9.96		
Channel							10.02	
Site 1	10	10.9	9.6	11.6	8.7	10.16		
Site 2	9.2	12	10.5	9.4	9.9	10.2		
Site 3	10.2	9.6	10	8.4	9.5	9.54		
Site 4	10.2	10	9.7	9.9	10	9.96		
Site 5	9.1	10	10.5	10.6	9.9	10.02		
Site 6	10.2	10.7	9.8	9.7	10.8	10.24		
Pellowe							10.02	
Site 1	9.8	10.5	10	11.6	9.9	10.36		
Site 2	9.9	10.3	9.3	10	10.1	9.92		
Site 3	11.2	10.8	10	9.5	9.4	10.18		
Site 4	8.5	10.1	10.4	10.4	10	9.88		
Site 5	10.2	10.2	9.6	9.8	9.6	9.88		
Site 6	10.4	9.1	10	9.6	10.5	9.92		
St. Crispins							9.86	
Site 1	10.9	9.7	9.1	11.1	9.9	10.14		
Site 2	8.6	9.7	10	10.7	10.2	9.84		
Site 3	9.2	10.1	8.3	9.4	10.4	9.48		
Site 4	10.5	9.3	10	10.8	10.5	10.22		
Site 5	10.4	9.2	9.7	9	9.8	9.62		
Site 6	9.9	10.4	10.4	10.1	8.6	9.88		

Appendix 2 (continued). Width Estimation for Each Transect.

Reef/Site		#1	#2	#3	#4	#5	Mean	Reef mean
Escape								9.92
	Site 1	9.5	11.1	9.7	10	10.4	10.14	
	Site 2	8.5	10	9.7	9.6	11.4	9.84	
	Site 3	10.6	9.3	8.8	10.9	9.8	9.88	
	Site 4	9.7	9.6	10.4	10.1	10	9.96	
	Site 5	8.7	9.6	8.5	10.4	10.8	9.6	
	Site 6	10.6	10.1	10.7	9.1	10.1	10.12	
Ruby								10.13
	Site 1	10.7	9.2	9.4	10.1	10	9.88	
	Site 2	9.3	11.6	11.2	11.1	9.1	10.46	
	Site 3	9.7	10.7	10.1	10	10.3	10.16	
	Site 4	9.2	9.7	10.7	9.8	10.6	10	
	Site 5	11.7	8.7	9.5	11.4	9	10.06	
	Site 6	10.2	10.1	10.1	10.2	10.4	10.2	
Ribbon #4								10.03
	Site 1	10.4	9.4	10.5	10.5	9	9.96	
	Site 2	9.6	10	10.4	10.5	10	10.1	
	Site 3	not recorded						
	Site 4	not recorded						
	Site 5	not recorded						
	Site 6	not recorded						

Fish #	Actual TL (cm)	Est. TL: 1 (cm)	Error (cm)	Error/TL (%)	Est. TL: 2 (cm)	Error (cm)	Error/TL (%)
1	48	45	-3	6.25	50	2	4.17
2	38	36	-2	5.26	39	1	2.63
3	26	26	0	0.00	26	0	0.00
4	44	38	-6	13.64	46	2	4.55
5	36	36	0	0.00	40	4	11.11
6	57	55	-2	3.51	52	-5	8.77
7	88	88	0	0.00	88	0	0.00
8	70	68	-2	2.86	68	-2	2.86
9	47	43	-4	8.51	47	0	0.00
10	6	6	0	0.00	6	0	0.00
11	18	18	0	0.00	18	0	0.00
12	43	42	-1	2.33	44	1	2.33
13	77	72	-5	6.49	80	3	3.90
14	64	57	-7	10.94	65	1	1.56
15	66	65	-1	1.52	65	-1	1.52
16	12	12	0	0.00	12	0	0.00
17	60	50	-10	16.67	62	2	3.33
18	40	40	0	0.00	42	2	5.00
19	41	38	-3	7.32	43	2	4.88
20	78	73	-5	6.41	74	-4	5.13
21	24	24	0	0.00	28	4	16.67
22	68	65	-3	4.41	67	-1	1.47
23	50	47	-3	6.00	46	-4	8.00
24	28	28	0	0.00	29	1	3.57
25	75	76	1	1.33	67	-8	10.67
26	40	40	0	0.00	40	0	0.00
27	58	58	0	0.00	55	-3	5.17
28	58	58	0	0.00	57	-1	1.72
29	53	52	-1	1.89	60	7	13.21
30	52	54	2	3.85	48	-4	7.69
31	61	58	-3	4.92	60	-1	1.64
32	49	46	-3	6.12	48	-1	2.04
33	30	32	2	6.67	32	2	6.67
34	76	76	0	0.00	75	-1	1.32
35	32	35	3	9.38	32	0	0.00
36	62	62	0	0.00	60	-2	3.23
37	45	46	1	2.22	44	-1	2.22
38	53	52	-1	1.89	53	0	0.00
39	46	44	-2	4.35	50	4	8.70
40	22	25	3	13.64	24	2	9.09
41	82	85	3	3.66	68	-14	17.07
42	55	53	-2	3.64	52	-3	5.45
43	36	37	1	2.78	35	-1	2.78
44	75	72	-3	4.00	68	-7	9.33
45	42	42	0	0.00	42	0	0.00
46	62	60	-2	3.23	60	-2	3.23
47	34	34	0	0.00	34	0	0.00
Mean	49.51	48.28	-1.23	3.74	48.96	-0.55	4.31

APPENDIX 4. ANALYSIS OF VARIANCE TABLES

Where the raw data has been either log normal (Ln) or square-root (Sqrt) transformed after the addition of 1.0 or 0.5 to each datum respectively, this is noted after the species label. See table 2 in the main body of the report for analysis details.

A. Comparison of Protected/Opened and Fished Reefs (5+5 reefs).

Source of Variation	df	MS	F	p	MS	F	p
		Plectropomus leopardus			*P. leopardus* recruits		
Habitat	1	60.802	64.227	<0.001	0.135	0.920	0.340
Zone	1	2.802	2.960	0.089	0.135	0.920	0.340
Reef (Z)	8	60.721	64.142	<0.001	0.822	5.608	<0.001
Site (HZRY)	80	0.947	0.937	0.631	0.147	1.709	<0.001
Year	1	9.882	10.438	0.002	0.002	0.011	0.915
H x Z	1	0.602	0.636	0.428	0.042	0.284	0.596
H x R(Z)	8	3.606	3.809	<0.001	0.026	0.176	0.994
H x Y	1	1.815	1.917	0.170	0.482	3.284	0.074
Z x Y	1	0.042	0.044	0.834	0.002	0.011	0.915
R x Y(Z)	8	1.441	1.522	0.163	0.048	0.324	0.955
H x Z x Y	1	2.802	2.960	0.089	0.375	2.557	0.114
H x R x Y(Z)	8	1.546	1.633	0.129	0.174	1.187	0.317
Residual	480	1.010			0.086		
		P. leopardus <35 cm TL			*P. leopardus* >35 cm TL - Ln		
Habitat	1	10.935	14.263	<0.001	6.345	56.437	<0.001
Zone	1	3.082	4.020	0.048	0.065	0.575	0.450
Reef (Z)	8	21.603	28.178	<0.001	3.270	29.089	<0.001
Site (HZRY)	80	0.737	1.347	0.033	0.112	0.668	0.986
Year	1	1.602	2.089	0.152	0.732	6.508	0.013
H x Z	1	1.602	2.089	0.152	0.052	0.459	0.500
H x R(Z)	8	1.518	1.980	0.060	0.612	5.448	<0.001
H x Y	1	0.482	0.628	0.430	0.148	1.315	0.255
Z x Y	1	0.082	0.107	0.745	0.048	0.426	0.516
R x Y(Z)	8	0.492	0.641	0.741	0.166	1.475	0.180
H x Z x Y	1	0.375	0.489	0.486	0.441	3.923	0.051
H x R x Y(Z)	8	0.420	0.548	0.817	0.169	1.502	0.170
Residual	480	0.569			0.168		
		Plectropomus laevis			Total Lethrinids - Ln		
Habitat	1	0.000	0.000	1.00	0.256	0.470	0.495
Zone	1	1.127	6.202	0.015	2.022	3.719	0.057
Reef (Z)	8	1.131	6.225	<0.001	3.141	5.776	<0.001
Site (HZRY)	80	0.182	0.823	0.859	0.544	2.468	<0.001
Year	1	0.667	3.670	0.059	0.352	0.647	0.424
H x Z	1	0.960	5.284	0.024	0.309	0.567	0.454
H x R(Z)	8	0.359	1.977	0.060	0.532	0.978	0.459
H x Y	1	0.060	0.330	0.567	0.891	1.639	0.204
Z x Y	1	0.027	0.147	0.703	0.599	1.101	0.297
R x Y(Z)	8	0.168	0.922	0.503	0.191	0.351	0.943
H x Z x Y	1	0.060	0.330	0.567	0.024	0.043	0.836
H x R x Y(Z)	8	0.356	1.959	0.063	0.510	0.937	0.491
Residual	480	0.221			0.220		

A. Comparison of All Protected/Opened and Fished Reefs (continued).

Source of Variation	df	MS	F	p	MS	F	p
		Lethrinus atkinsoni - Ln			*Lethrinus obsoletus* - Ln		
Habitat	1	0.109	0.274	0.602	2.626	31.167	<0.001
Zone	1	0.016	0.041	0.840	0.111	1.313	0.255
Reef (Z)	8	2.168	5.433	<0.001	0.088	1.047	0.409
Site (HZRY)	80	0.399	2.401	<0.001	0.084	2.035	<0.001
Year	1	0.156	0.392	0.533	0.178	2.117	0.150
H x Z	1	0.132	0.332	0.566	0.111	1.313	0.255
H x R(Z)	8	0.389	0.974	0.462	0.138	1.633	0.128
H x Y	1	0.409	1.025	0.314	0.178	2.117	0.150
Z x Y	1	1.207	3.025	0.086	0.170	2.022	0.159
R x Y(Z)	8	0.095	0.238	0.982	0.163	1.936	0.066
H x Z x Y	1	0.227	0.568	0.453	0.035	0.412	0.523
H x R x Y(Z)	8	0.390	0.978	0.459	0.213	2.525	0.017
Residual	480	0.166			0.041		
		Lethrinus miniatus			*Monotaxis grandoculis* - Ln		
Habitat	1	0.338	1.884	0.180	8.245	15.171	<0.001
Zone	1	1.837	10.256	0.003	0.441	0.812	0.370
Reef (Z)	8	0.604	3.372	0.047	5.369	9.879	<0.001
Site (HZRY)	80	0.179	1.720	0.014	0.543	1.585	0.002
Year	1	0.338	1.884	0.180	0.645	1.186	0.279
H x Z	1	0.038	0.209	0.650	0.013	0.024	0.878
H x R(Z)	8	0.021	0.116	0.891	0.694	1.276	0.268
H x Y	1	0.104	0.581	0.451	0.046	0.085	0.772
Z x Y	1	0.204	1.140	0.294	0.747	1.374	0.245
R x Y(Z)	8	0.104	0.581	0.565	0.483	0.889	0.529
H x Z x Y	1	0.204	1.140	0.294	0.192	0.353	0.554
H x R x Y(Z)	8	0.854	4.767	0.015	0.643	1.184	0.319
Residual	480	0.104			0.343		
		Total Lutjanids - Sqrt			*Lutjanus gibbus* - Sqrt		
Habitat	1	22.763	13.116	<0.001	20.293	40.238	<0.001
Zone	1	1.468	0.846	0.361	4.087	8.105	0.006
Reef (Z)	8	13.599	7.836	<0.001	5.203	10.316	<0.001
Site (HZRY)	80	1.736	2.880	<0.001	0.504	2.140	<0.001
Year	1	3.902	2.248	0.138	0.178	0.354	0.554
H x Z	1	20.166	11.619	0.001	10.646	21.110	<0.001
H x R(Z)	8	8.652	4.986	<0.001	3.514	6.968	<0.001
H x Y	1	0.009	0.005	0.943	1.031	2.045	0.157
Z x Y	1	5.051	2.910	0.092	2.029	4.024	0.048
R x Y(Z)	8	0.625	0.360	0.938	0.514	1.019	0.429
H x Z x Y	1	3.281	1.890	0.173	0.161	0.320	0.573
H x R x Y(Z)	8	1.617	0.932	0.495	0.601	1.192	0.315
Residual	480	0.603			0.236		
		Lutjanus bohar - Ln			*Lutjanus carponotatus*		
Habitat	1	8.350	13.607	<0.001	0.882	2.251	0.138
Zone	1	0.265	0.433	0.513	8.882	22.677	<0.001
Reef (Z)	8	2.875	4.685	<0.001	3.178	8.113	<0.001
Site (HZRY)	80	0.614	2.378	<0.001	0.392	2.554	<0.001
Year	1	0.017	0.028	0.869	0.282	0.719	0.399
H x Z	1	0.000	0.000	0.983	1.215	3.102	0.082
H x R(Z)	8	1.683	2.742	0.010	0.728	1.857	0.079
H x Y	1	0.048	0.078	0.781	0.282	0.719	0.399
Z x Y	1	0.473	0.770	0.383	0.135	0.345	0.559
R x Y(Z)	8	0.470	0.766	0.634	0.204	0.521	0.837
H x Z x Y	1	1.532	2.497	0.118	0.135	0.345	0.559
H x R x Y(Z)	8	0.496	0.808	0.597	0.121	0.309	0.961
Residual	480	0.258			0.153		

A. Comparison of All Protected/Opened and Fished Reefs (continued).

Source of Variation	df	MS	F	p	MS	F	p
		Lutjanus fulviflamma			Chaetodontids- Sqrt		
Habitat	1	8.882	2.276	0.135	10.888	10.147	0.002
Zone	1	8.402	2.153	0.146	1.871	1.743	0.191
Reef (Z)	8	5.831	1.494	0.172	21.145	19.706	<0.001
Site (HZRY)	80	3.902	3.695	<0.001	1.073	3.049	<0.001
Year	1	4.002	1.026	0.314	1.446	1.348	0.249
H x Z	1	17.682	4.532	0.036	2.202	2.052	0.156
H x R(Z)	8	5.694	1.459	0.185	5.375	5.009	<0.001
H x Y	1	0.082	0.021	0.885	1.299	1.211	0.275
Z x Y	1	0.082	0.021	0.885	4.404	4.104	0.046
R x Y(Z)	8	1.546	0.396	0.917	0.813	0.758	0.641
H x Z x Y	1	0.602	0.154	0.696	0.032	0.030	0.864
H x R x Y(Z)	8	1.096	0.281	0.971	0.756	0.705	0.686
Residual	480	1.056			0.352		
		Coral Chaets - Sqrt			*Pomacent.moluccensis* - Sqrt		
Habitat	1	38.489	41.641	<0.001	462.71	114.0	<0.001
Zone	1	0.445	0.481	0.490	45.397	11.179	0.001
Reef (Z)	8	16.154	17.477	<0.001	36.566	9.005	<0.001
Site (HZRY)	80	0.924	2.667	<0.001	4.061	4.745	<0.001
Year	1	5.221	5.649	0.020	0.133	0.033	0.857
H x Z	1	3.785	4.095	0.046	8.986	2.213	0.141
H x R(Z)	8	10.833	11.721	<0.001	8.027	1.977	0.060
H x Y	1	0.107	0.115	0.735	1.693	0.417	0.520
Z x Y	1	3.134	3.390	0.069	0.900	0.222	0.639
R x Y(Z)	8	1.579	1.708	0.109	5.626	1.385	0.216
H x Z x Y	1	0.666	0.720	0.399	0.105	0.026	0.873
H x R x Y(Z)	8	0.704	0.761	0.637	4.782	1.177	0.323
Residual	480	0.347			0.856		
		Ambly. curacao - Ln			*Chrysiptera rollandi* - Sqrt		
Habitat	1	59.359	64.071	<0.001	1356.0	78.014	<0.001
Zone	1	0.351	0.379	0.540	264.007	15.189	<0.001
Reef (Z)	8	6.216	6.709	<0.001	125.890	7.243	<0.001
Site (HZRY)	80	0.926	3.248	<0.001	17.382	3.974	<0.001
Year	1	1.182	1.275	0.262	0.060	0.003	0.953
H x Z	1	0.327	0.353	0.554	79.207	4.557	0.036
H x R(Z)	8	1.283	1.385	0.216	112.198	6.455	<0.001
H x Y	1	0.269	0.290	0.592	21.660	1.246	0.268
Z x Y	1	0.170	0.183	0.670	28.167	1.620	0.207
R x Y(Z)	8	0.317	0.342	0.947	7.663	0.441	0.893
H x Z x Y	1	0.998	1.077	0.302	62.727	3.609	0.061
H x R x Y(Z)	8	0.328	0.354	0.941	21.602	1.243	0.286
Residual	480	0.285			4.373		
		Plectroglyphidodon dickii			*Plect. lacrymatus* - Sqrt		
Habitat	1	197.227	43.031	<0.001	0.055	0.026	0.872
Zone	1	0.167	0.036	0.849	12.326	5.879	0.018
Reef (Z)	8	34.592	7.547	<0.001	6.108	2.914	0.007
Site (HZRY)	80	4.583	3.879	<0.001	2.097	2.931	<0.001
Year	1	0.107	0.023	0.879	0.370	0.177	0.675
H x Z	1	0.667	0.145	0.704	8.828	4.211	0.043
H x R(Z)	8	35.830	7.817	<0.001	14.916	7.115	<0.001
H x Y	1	0.327	0.071	0.790	5.518	2.632	0.109
Z x Y	1	15.360	3.351	0.071	0.582	0.278	0.600
R x Y(Z)	8	5.558	1.213	0.302	4.062	1.938	0.066
H x Z x Y	1	18.727	4.086	0.047	0.247	0.118	0.732
H x R x Y(Z)	8	4.943	1.079	0.387	1.154	0.550	0.815
Residual	480	1.182			0.715		

A. Comparison of All Protected/Opened and Fished Reefs (continued).

Source of Variation	df	MS	F	p	MS	F	p
		Hard Coral Cover - Ln			Soft Coral Cover - Sqrt		
Habitat	1	0.641	1.033	0.312	8.864	1.913	0.170
Zone	1	0.003	0.004	0.948	94.966	20.500	<0.001
Reef (Z)	8	6.225	10.041	<0.001	48.944	10.565	<0.001
Site (HZRY)	80	0.620	3.131	<0.001	4.633	5.923	<0.001
Year	1	32.235	51.993	<0.001	9.683	2.090	0.152
H x Z	1	0.554	0.894	0.347	20.195	4.359	0.040
H x R(Z)	8	6.481	10.454	<0.001	55.049	11.883	<0.001
H x Y	1	0.033	0.053	0.819	3.522	0.760	0.386
Z x Y	1	0.151	0.244	0.623	0.142	0.031	0.862
R x Y(Z)	8	0.602	0.970	0.465	4.058	0.876	0.540
H x Z x Y	1	0.053	0.086	0.770	3.844	0.830	0.365
H x R x Y(Z)	8	1.005	1.621	0.132	4.876	1.053	0.405
Residual	480	0.198			0.782		

B. Balanced Eight Reef Analysis.

Source of Variation	df	MS	F	p	MS	F	p
		Plectropomus leopardus			*P. leopardus* recruits		
Habitat	1	58.102	50.432	<0.001	0.169	0.920	0.341
Shelf Position	1	321.77	279.0	<0.001	4.219	23.011	<0.001
Zone	1	3.169	2.750	0.102	0.169	0.920	0.341
Reef (PZ)	4	9.394	8.154	<0.001	0.285	1.557	0.197
Site (HPZRY)	64	1.152	0.964	0.557	0.183	1.709	0.001
Year	1	7.752	6.729	0.012	0.002	0.011	0.915
H x P	1	11.719	10.179	0.002	0.019	0.102	0.750
H x Z	1	0.169	0.146	0.703	0.052	0.284	0.596
H x R(PZ)	4	2.694	2.338	0.065	0.010	0.057	0.994
H x Y	1	1.302	1.130	0.292	0.602	3.284	0.075
H x P x Z	1	3.852	3.344	0.072	0.102	0.557	0.458
H x P x Y	1	0.052	0.045	0.832	0.252	1.375	0.245
H x Z x Y	1	2.002	1.738	0.192	0.469	2.557	0.115
H x R x Y(PZ)	4	3.060	2.656	0.041	0.144	0.784	0.540
H x P x Z x Y	1	0.019	0.016	0.899	0.352	1.920	0.171
P x Z	1	3.169	2.750	0.102	0.102	0.557	0.458
P x Y	1	0.052	0.045	0.832	0.102	0.557	0.458
P x Z x Y	1	0.019	0.016	0.899	0.002	0.011	0.915
R x Y(PZ)	4	2.860	2.483	0.052	0.069	0.375	0.826
Z x Y	1	0.019	0.016	0.899	0.002	0.011	0.915
Residual	384	1.195			0.107		
		P. leopardus <35 cm TL			*P. leopardus* >35 cm TL - Ln		
Habitat	1	12.352	13.059	<0.001	4.965	36.888	<0.001
Shelf Position	1	117.019	123.72	<0.001	14.850	110.0	<0.001
Zone	1	3.852	7.073	0.048	0.134	0.996	0.322
Reef (PZ)	4	3.423	3.619	0.010	0.954	7.085	<0.001
Site (HPZRY)	64	0.946	1.367	0.041	0.135	0.721	0.945
Year	1	1.102	1.165	0.284	0.559	4.157	0.046
H x P	1	0.169	0.178	0.674	3.317	24.641	<0.001
H x Z	1	1.519	1.606	0.210	0.181	1.345	0.251
H x R(PZ)	4	1.131	1.196	0.321	0.285	2.120	0.088
H x Y	1	0.352	0.372	0.544	0.121	0.900	0.346
H x P x Z	1	5.852	6.187	0.016	0.191	1.423	0.237
H x P x Y	1	0.019	0.020	0.889	0.019	0.144	0.705
H x Z x Y	1	0.252	0.267	0.608	0.326	2.424	0.124
H x R x Y(PZ)	4	0.831	0.879	0.482	0.331	2.458	0.054
H x P x Z x Y	1	0.002	0.002	0.963	0.006	0.044	0.834
P x Z	1	0.002	0.002	0.963	1.239	9.208	0.004
P x Y	1	0.019	0.020	0.889	0.249	1.848	0.179
P x Z x Y	1	0.169	0.178	0.674	0.045	0.335	0.565
R x Y(PZ)	4	0.923	0.976	0.427	0.258	1.916	0.119
Z x Y	1	0.102	0.108	0.744	0.040	0.297	0.588
Residual	384	0.692			0.187		

B. Balanced Eight Reef Analysis (continued).

Source of Variation	df	MS	F	p	MS	F	p
		Plectropomus laevis			Total Lethrinids - Ln		
Habitat	1	0.033	0.174	0.678	0.298	0.502	0.481
Shelf Position	1	3.008	15.696	<0.001	20.087	33.840	<0.001
Zone	1	1.200	6.261	0.015	2.414	4.067	0.048
Reef (PZ)	4	1.254	6.543	<0.001	0.761	1.283	0.286
Site (HPZRY)	64	0.192	0.783	0.884	0.594	2.842	<0.001
Year	1	0.533	2.783	0.100	0.449	0.756	0.388
H x P	1	0.833	4.348	0.041	0.966	1.627	0.207
H x Z	1	0.408	2.130	0.149	0.023	0.039	0.843
H x R(PZ)	4	0.296	1.543	0.200	0.277	0.467	0.760
H x Y	1	0.208	1.087	0.301	0.105	0.177	0.675
H x P x Z	1	0.408	2.130	0.149	0.025	0.042	0.839
H x P x Y	1	0.208	1.087	0.301	0.146	0.245	0.622
H x Z x Y	1	0.033	0.174	0.678	0.001	0.002	0.964
H x R x Y(PZ)	4	0.554	2.891	0.029	0.611	1.030	0.399
H x P x Z x Y	1	0.133	0.696	0.407	0.083	0.139	0.711
P x Z	1	0.033	0.174	0.678	0.563	0.949	0.334
P x Y	1	0.000	0.000	1.000	0.387	0.651	0.423
P x Z x Y	1	0.408	2.130	0.149	0.718	1.210	0.275
R x Y(PZ)	4	0.112	0.587	0.673	0.062	0.105	0.980
Z x Y	1	0.208	1.087	0.301	0.326	0.549	0.462
Residual	384	0.245			0.209		
		Lethrinus atkinsoni - Ln			*Lethrinus obsoletus* - Ln		
Habitat	1	0.008	0.019	0.891	1.576	23.197	<0.001
Shelf Position	1	14.045	32.605	<0.001	0.178	2.622	0.110
Zone	1	0.059	0.138	0.712	0.104	1.524	0.222
Reef (PZ)	4	0.279	0.648	0.631	0.068	1.007	0.411
Site (HPZRY)	64	0.431	2.754	<0.001	0.068	1.835	<0.001
Year	1	0.413	0.959	0.331	0.087	1.285	0.261
H x P	1	0.477	1.106	0.297	0.456	6.709	0.012
H x Z	1	0.025	0.057	0.812	0.104	1.524	0.222
H x R(PZ)	4	0.290	0.672	0.614	0.076	1.125	0.353
H x Y	1	0.006	0.013	0.909	0.087	1.285	0.261
H x P x Z	1	0.101	0.235	0.629	0.148	2.182	0.145
H x P x Y	1	0.205	0.475	0.493	0.081	1.193	0.279
H x Z x Y	1	0.342	0.794	0.376	0.067	0.983	0.325
H x R x Y(PZ)	4	0.169	0.392	0.814	0.153	2.256	0.073
H x P x Z x Y	1	0.021	0.048	0.828	0.932	13.714	<0.001
P x Z	1	0.624	1.450	0.233	0.148	2.182	0.145
P x Y	1	0.115	0.266	0.608	0.081	1.193	0.279
P x Z x Y	1	0.001	0.003	0.956	0.507	7.465	0.008
R x Y(PZ)	4	0.023	0.053	0.995	0.145	2.138	0.086
Z x Y	1	0.668	1.552	0.217	0.262	3.852	0.054
Residual	384	0.156			0.037		

B. Balanced Eight Reef Analysis (continued).

Source of Variation	df	MS	F	p	MS	F	p
		Monotaxis grandoculis - Ln			Total Lutjanids - Sqrt		
Habitat	1	6.160	13.466	<0.001	22.124	11.299	0.001
Shelf Position	1	25.927	56.676	<0.001	33.343	17.029	<0.001
Zone	1	2.412	5.273	0.025	2.164	1.105	0.297
Reef (PZ)	4	0.499	1.092	0.368	12.885	6.581	<0.001
Site (HPZRY)	64	0.457	1.347	0.049	1.958	3.332	<0.001
Year	1	1.070	2.339	0.131	2.221	1.134	0.291
H x P	1	0.221	0.483	0.489	20.322	10.397	0.002
H x Z	1	0.044	0.097	0.757	29.883	15.261	<0.001
H x R(PZ)	4	1.009	2.207	0.078	9.354	4.777	0.002
H x Y	1	0.382	0.836	0.364	0.546	0.279	0.599
H x P x Z	1	1.194	2.610	0.111	0.017	0.009	0.927
H x P x Y	1	1.154	2.522	0.117	0.764	0.390	0.535
H x Z x Y	1	0.852	1.863	0.177	1.828	0.934	0.338
H x R x Y(PZ)	4	0.307	0.672	0.614	1.785	0.911	0.463
H x P x Z x Y	1	0.443	0.969	0.329	1.281	0.654	0.422
P x Z	1	1.167	2.551	0.115	12.784	6.529	0.013
P x Y	1	1.131	2.472	0.121	0.909	0.464	0.498
P x Z x Y	1	0.214	0.467	0.497	0.256	0.131	0.719
R x Y(PZ)	4	0.366	0.801	0.529	0.829	0.423	0.791
Z x Y	1	0.193	0.421	0.519	3.403	1.738	0.192
Residual	384	0.340			0.588		
		Lutjanus gibbus - Sqrt			*Lutjanus bohar* - Ln		
Habitat	1	14.841	28.233	<0.001	10.353	14.589	<0.001
Shelf Position	1	29.590	56.291	<0.001	15.152	21.351	<0.001
Zone	1	4.432	8.432	0.005	0.814	1.147	0.288
Reef (PZ)	4	1.931	3.674	0.009	1.561	2.200	0.079
Site (HPZRY)	64	0.526	2.470	<0.001	0.710	2.892	<0.001
Year	1	0.032	0.060	0.807	0.069	0.097	0.756
H x P	1	12.874	24.491	<0.001	0.706	0.995	0.322
H x Z	1	14.727	28.016	<0.001	0.117	0.165	0.686
H x R(PZ)	4	1.785	3.396	0.014	2.516	3.546	0.011
H x Y	1	0.694	1.320	0.255	0.425	0.598	0.442
H x P x Z	1	3.717	7.072	0.010	0.049	0.069	0.794
H x P x Y	1	0.371	0.706	0.404	0.627	0.883	0.351
H x Z x Y	1	0.000	0.000	0.988	1.072	1.511	0.224
H x R x Y(PZ)	4	0.749	1.424	0.236	0.467	0.657	0.624
H x P x Z x Y	1	0.726	1.382	0.244	0.410	0.578	0.450
P x Z	1	3.505	6.669	0.012	0.128	0.180	0.673
P x Y	1	0.675	1.283	0.262	0.066	0.093	0.762
P x Z x Y	1	0.019	0.037	0.849	0.620	0.874	0.353
R x Y(PZ)	4	0.782	1.487	0.217	0.586	0.826	0.513
Z x Y	1	1.301	2.474	0.121	0.429	0.605	0.440
Residual	384	0.213			0.245		

B. Balanced Eight Reef Analysis (continued).

Source of Variation	df	MS	F	p	MS	F	p
		Lutjanus carponotatus			*Lutjanus fulviflamma*		
Habitat	1	1.008	2.086	0.154	13.333	2.792	0.100
Shelf Position	1	12.675	26.224	<0.001	0.675	0.141	0.708
Zone	1	10.800	22.345	<0.001	8.533	1.787	0.186
Reef (PZ)	4	0.196	0.405	0.804	6.671	1.397	0.245
Site (HPZRY)	64	0.483	2.607	<0.001	4.775	3.921	<0.001
Year	1	0.300	0.621	0.434	3.675	0.770	0.384
H x P	1	0.208	0.431	0.514	7.500	1.571	0.215
H x Z	1	1.633	3.379	0.071	25.208	5.279	0.025
H x R(PZ)	4	1.129	2.336	0.065	5.562	1.165	0.335
H x Y	1	0.300	0.621	0.434	0.000	0.000	1.000
H x P x Z	1	0.533	1.103	0.298	3.008	0.630	0.430
H x P x Y	1	0.300	0.621	0.424	4.800	1.005	0.320
H x Z x Y	1	0.208	0.431	0.514	1.408	0.295	0.589
H x R x Y(PZ)	4	0.087	0.181	0.947	0.587	0.123	0.974
H x P x Z x Y	1	0.208	0.431	0.514	0.075	0.016	0.901
P x Z	1	7.500	15.517	<0.001	13.333	2.792	0.100
P x Y	1	0.300	0.621	0.434	0.008	0.002	0.967
P x Z x Y	1	0.075	0.155	0.695	5.633	1.180	0.282
R x Y(PZ)	4	0.304	0.629	0.643	1.579	0.331	0.856
Z x Y	1	0.075	0.155	0.695	0.000	0.000	1.000
Residual	384	0.185			1.218		
		Chaetodontids - Sqrt			Coral Chaets - Sqrt		
Habitat	1	0.357	0.297	0.587	5.495	6.040	0.017
Shelf Position	1	148.115	123.0	<0.001	109.158	120.0	<0.001
Zone	1	0.004	0.004	0.952	0.663	0.728	0.397
Reef (PZ)	4	2.641	2.199	0.079	1.966	2.160	0.084
Site (HPZRY)	64	1.201	3.456	<0.001	0.910	2.574	<0.001
Year	1	0.554	0.462	0.499	5.671	6.233	0.015
H x P	1	8.200	6.827	0.011	20.438	22.463	<0.001
H x Z	1	1.186	0.987	0.324	1.782	1.958	0.167
H x R(PZ)	4	1.151	0.958	0.437	2.845	3.126	0.021
H x Y	1	0.053	0.044	0.834	0.101	0.110	0.741
H x P x Z	1	2.212	1.841	0.180	2.677	2.942	0.091
H x P x Y	1	0.142	0.118	0.732	1.125	1.236	0.270
H x Z x Y	1	0.427	0.355	0.553	0.653	0.718	0.400
H x R x Y(PZ)	4	0.047	0.039	0.997	0.540	0.593	0.669
H x P x Z x Y	1	1.392	1.159	0.286	0.462	0.507	0.479
P x Z	1	3.662	3.049	0.086	1.213	1.334	0.253
P x Y	1	0.017	0.014	0.906	0.962	1.058	0.308
P x Z x Y	1	0.401	0.334	0.566	1.395	1.534	0.220
R x Y(PZ)	4	1.311	1.092	0.368	2.405	2.643	0.042
Z x Y	1	2.669	7.680	0.006	2.115	2.325	0.132
Residual	384	0.348			0.353		

B. Balanced Eight Reef Analysis (continued).

Source of Variation	df	MS	F	p	MS	F	p
		Pomacent. moluccensis - Sqrt			*Ambly. curacao* - Ln		
Habitat	1	427.998	88.318	<0.001	42.331	40.824	<0.001
Shelf Position	1	145.901	30.107	<0.001	30.213	29.137	<0.001
Zone	1	55.984	11.552	0.001	0.293	0.282	0.597
Reef (PZ)	4	5.356	1.105	0.362	2.586	2.494	0.052
Site (HPZRY)	64	4.846	4.959	<0.001	1.037	3.165	<0.001
Year	1	0.329	0.068	0.795	1.046	1.009	0.319
H x P	1	8.823	1.821	0.182	5.106	4.924	0.030
H x Z	1	10.895	2.248	0.139	0.269	0.259	0.612
H x R(PZ)	4	10.728	2.214	0.077	1.033	0.996	0.416
H x Y	1	0.223	0.046	0.831	0.150	0.144	0.705
H x P x Z	1	0.078	0.016	0.900	0.284	0.274	0.602
H x P x Y	1	16.965	3.501	0.066	0.892	0.861	0.357
H x Z x Y	1	0.015	0.003	0.956	1.202	1.159	0.286
H x R x Y(PZ)	4	3.751	0.774	0.546	0.238	0.230	0.921
H x P x Z x Y	1	3.754	0.775	0.382	0.542	0.523	0.472
P x Z	1	15.229	3.143	0.081	1.078	1.040	0.312
P x Y	1	26.678	5.505	0.022	0.700	0.675	0.414
P x Z x Y	1	6.948	1.434	0.236	0.200	0.193	0.662
R x Y(PZ)	4	1.830	0.378	0.824	0.399	0.385	0.819
Z x Y	1	0.671	0.139	0.711	0.194	0.591	0.443
Residual	384	0.977			0.328		
		Chrysiptera rollandi - Sqrt			*Plect. lacrymatus* - Sqrt		
Habitat	1	124.835	131.0	<0.001	13.845	5.913	0.018
Shelf Position	1	16.729	17.555	<0.001	0.118	0.050	0.823
Zone	1	18.281	19.183	<0.001	10.785	4.606	0.036
Reef (PZ)	4	2.359	2.476	0.053	11.414	4.875	0.002
Site (HPZRY)	64	0.953	3.344	<0.001	2.342	3.044	<0.001
Year	1	0.441	0.462	0.499	1.981	0.846	0.361
H x P	1	0.379	0.398	0.531	4.609	1.968	0.166
H x Z	1	3.453	3.623	0.062	4.985	2.129	0.149
H x R(PZ)	4	9.225	9.681	<0.001	8.872	3.789	0.008
H x Y	1	0.666	0.698	0.406	2.294	0.980	0.326
H x P x Z	1	1.523	1.598	0.211	1.103	0.471	0.495
H x P x Y	1	1.233	1.294	0.260	1.228	0.524	0.472
H x Z x Y	1	4.496	4.718	0.034	0.280	0.119	0.731
H x R x Y(PZ)	4	1.817	1.906	0.120	1.562	0.667	0.617
H x P x Z x Y	1	0.397	0.417	0.521	0.003	0.001	0.974
P x Z	1	13.333	13.991	<0.001	0.925	0.395	0.532
P x Y	1	0.136	0.143	0.707	4.311	1.841	0.180
P x Z x Y	1	0.012	0.013	0.910	6.668	2.848	0.096
R x Y(PZ)	4	0.443	0.465	0.761	4.429	1.891	0.123
Z x Y	1	1.900	6.668	0.010	0.652	0.278	0.600
Residual	384	0.285			0.769		

B. Balanced Eight Reef Analysis (continued).

Source of Variation	df	MS	F	p	MS	F	p
		Hard Coral Cover			Soft Coral Cover		
Habitat	1	5.137	10.062	0.002	100.304	19.937	<0.001
Shelf Position	1	37.207	72.884	<0.001	237.658	47.238	<0.001
Zone	1	0.949	1.858	0.178	58.283	11.585	0.001
Reef (PZ)	4	0.803	1.572	0.192	29.358	5.835	<0.001
Site (HPZRY)	64	0.510	2.726	<0.001	5.031	7.101	<0.001
Year	1	27.372	53.619	<0.001	12.318	2.448	0.123
H x P	1	1.793	3.513	0.066	19.486	3.873	0.053
H x Z	1	0.200	0.391	0.534	13.092	2.602	0.112
H x R(PZ)	4	1.264	2.475	0.053	29.597	5.883	<0.001
H x Y	1	0.754	1.478	0.229	10.335	2.054	0.157
H x P x Z	1	0.291	0.570	0.453	31.433	6.248	0.015
H x P x Y	1	0.129	0.253	0.617	1.896	0.377	0.542
H x Z x Y	1	0.001	0.002	0.962	2.017	0.401	0.529
H x R x Y(PZ)	4	0.979	1.918	0.118	5.119	1.018	0.405
H x P x Z x Y	1	1.209	2.368	0.129	4.278	0.850	0.360
P x Z	1	0.038	0.074	0.786	4.349	0.864	0.356
P x Y	1	1.373	2.691	0.106	3.251	0.646	0.425
P x Z x Y	1	1.265	2.478	0.120	7.315	1.454	0.232
R x Y(PZ)	4	0.490	0.960	0.436	3.441	0.684	0.606
Z x Y	1	0.237	0.463	0.499	1.918	0.381	0.539
Residual	384	0.187			0.709		